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JOURNAL OF PALEONTOLOGY

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CONTENTS

Corals of the Independence shale of Iowa ..... *Merrill A. Stainbrook* 401
Upper Aptian nautiloids from Colombia ..... *J. Wyatt Durham* 428
Plemnocrinus, a new crinoid genus from the lower Mississippian ..... *Edwin Kirk* 435
Early Upper Cambrian trilobites from western Gaspé ..... *Franco Rasetti* 442
Siphogenerinoides Cushman (order Foraminifera, family Buliminidae) .. *Benton Stone* 463
A giant ammonite from the Cretaceous of Montana ..... *A. K. Miller and Walter Youngquist* 479
Late Tertiary fresh-water mollusks from southeastern Idaho ..... *Teng-Chien Yen* 485
Eocene nonmarine gastropods from Hot Spring County, Wyoming .. *Teng-Chien Yen* 495
Orientation of the crystal units of conodonts ..... *Wilbert H. Hass and Marie L. Lindberg* 501
A Lower Cretaceous fauna in the northwest basin of Western Australia .. *Irene Crespin* 505
Check list of the fossil fishes of New Jersey ..... *William F. Rapp, Jr.* 510
Optimum conditions for the photography of fossils ..... *Franco Rasetti* 514

PALEONTOLOGICAL NOTES
Deaderick collection of Foraminifera ..... *Lloyd G. Henbest* 517
Saltermya, new name for *Anthracomya* Salter 1861, not Rondani 1856 ..... *Katherine Van Winkle Palmer* 518

SOCIETY RECORDS AND ACTIVITIES
Annual meeting of The Paleontological Society 519

NOMENCLATURAL NOTES
Publications of the International Commission on Zoological Nomenclature .. 519

REVIEW
Geology as a profession, by Ann R. Taylor ..... *Chas. H. Behre, Jr.* 520

EDITORS

C. WYTHE COOKE, for The Paleontological Society.

J. MARVIN WELLER, for The Society of Economic Paleontologists and Mineralogists.

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CORALS OF THE INDEPENDENCE SHALE OF IOWA

MERRILL A. STAINBROOK

Texas Technological College, Lubbock, Texas

ABSTRACT—Seventeen species of Devonian corals are described and illustrated, all but two as new forms. They are placed in 13 genera of which one, *Plexituba*, a member of the Auloporidae, is diagnosed as new. Five genera—*Metriophyllum*, *Syringaxon*, *Caninia*, *Amplexus* and *Thamnopora*—are recognized for the first time as occurring in the Devonian of Iowa. Evidence afforded by the corals concerning the age and correlation of the Independence reinforces conclusions made in a previous study of the brachiopods of the formation.

INTRODUCTION

THE PRESENT paper is the third of a series on the fauna of the Independence shale of Iowa. One on the Foraminifera (Cushman and Stainbrook, 1943) and another on the brachiopods (Stainbrook, 1945a) have already appeared. Others on the remaining macrofossils and on the conodonts and ostracodes are in the course of preparation. The fauna of the Independence is generally unique and is not duplicated to any great extent elsewhere in the United States. It holds an important place in the determination of the age of several adjacent formations of the Devonian of Iowa and of the Upper Devonian of western North America.

The stratigraphy of the Independence shale was discussed by the writer at length in a previous paper (Stainbrook, 1945b) as some controversy had arisen regarding its geological position. It was maintained therein that the evidence available was consistent in placing the shales below the Cedar Valley limestone and above the Wapsipinicon formation. Similarities in the faunas of the Independence and several later formations were held to be due to descent rather than to synchroneity. Additional suites of samples from recently drilled wells have been recently received by the Iowa Geological Survey from localities near Shellsburg in Benton County, Center Point in Linn County, and near La Porte City, Eagle Center and Hicks in Black Hawk County. Their evidence corroborates that given in the paper cited above. The stratigraphic position of the shale appears to be in accord with the evidence afforded in this fauna by the association of certain genera and by the stage of evolution of the species.

The corals form an important part of the invertebrate fauna of the Independence shale, ranking next to the brachiopods, as is true of most other Devonian formations of Iowa. Although fewer in species and in number of individuals, they produce the largest specimens and appear to be more common than they actually are. The tetracorals are the more abundant. They are all

simple in type; no compound form has yet been secured after years of collecting. Tabulates are relatively rare and, with one exception, are sparse individually. Nevertheless, corals are of considerable interest, as among them are genera not previously encountered or noted in younger Devonian faunas of the state. Several genera are especially important in yielding evidence concerning the relative age of the shale and its correlation with strata of adjacent regions.

From a study of the brachiopods (Stainbrook, 1945a) the age of the Independence fauna was determined as early Upper Devonian comparable to the Cuboides fauna of the Frasnian of Europe as discussed by Williams (1890). The fauna of the shale was found to be distinct from that of the Cedar Valley, of the Shellrock limestone, of the Amana beds, of the Lime Creek beds—all of Iowa—and of the High Point of New York. The study of the corals brings out evidence reinforcing this age determination and shows nothing contradictory to or modifying the conclusions previously made.

In the Frasnian of Europe the coral genera *Metriophyllum* and *Macgeea* occur with *Phillipsastrea* and with the characteristic brachiopod genus *Hypothyridina*. This peculiar association is nearly duplicated in the Independence shale with the exception of the lack of *Phillipsastrea*. The absence of the latter is made up by the presence of genera of brachiopods, such as *Pugnoides*, *Productella*, *Gypidula*, *Aulacella*, and others common to the Independence and the Frasnian. This association of genera of corals and brachiopods appears to be more than coincidental and to indicate that the Independence is to be correlated with the Frasnian. *Macgeea* and *Phillipsastrea* do occur in the Lime Creek beds higher in the Devonian section of Iowa, but *Hypothyridina* and *Metriophyllum* do not, and the association is not that seen in the Independence shale.

The Tully limestone was mentioned as a possible correlative of the Independence shale as Williams (1890) had earlier thought that the Tully was equivalent to the beds bearing the Cuboides fauna in Europe. The common occurrence of the peculiar and, in America, vertically limited genera of *Metriophyllm* and d*Hypothyridina* in both Tully and Independence, is suggestive that the conclusion may be correct. Westward from New York the presence of *Metriophyllum* in the Olentangy shale of Ohio suggests that this shale may correlate with the Independence.

The corals of the Independence shale emphasize the distinctness of the fauna from that of the Lime Creek as noted in the study of the brachiopods. In the first place, no compound tetracoral is present in the Independence, and hence no representative of such characteristic Lime Creek genera as *Hexagonaria*, *Phillipsastrea*, "*Strombodes*," *Diphyphyllum*, and "*Smithia*" occurs therein. Likewise there are no Independence species of the Lime Creek genera of *Cystiphyllum*, *Chonophyllum* and *Heliophyllum* or of *Aulopora* and *Syringopora* among the tabulates. Five genera are represented in both terranes, namely *Macgeea*, *Charactophyllum*, *Tabulophyllum*, *Aulocaulis* and *Plexituba*, but in each instance by different species. *Alveolites* is present in both, also, but whether the species is the same cannot, at present, be determined because of the poor preservation of the form from the Independence. Conversely, several coral genera characteristic of the Independence, namely *Syringaxon*, *Metriophyllum*, *Caninia*, *Amplexus* and *Ceratopora* do not occur in the Lime Creek, although some may be present in the formations between.

Emphasizing the earlier Upper Devonian position of the Independence is the presence of the peculiar genus *Syringaxon*, which was previously known in the Niagaran of the Silurian. However a species has been noted recently in the Haragan shale of Oklahoma, of Helderbergian age. Thus two genera previously recognized in the Lower Devonian, *Syringaxon*, a coral, and *Skenidium*, a brachiopod, are found to range upward into the early Upper Devonian. In the Haragan shale also occurs the coral genus *Enterolasma*, which has uncinate carinae comparable to those of *Metriophyllum*, suggesting, perhaps, that the former is ancestral to the latter genus.

As indicated by the corals, the relationship of the Independence fauna to that of the Amana beds is somewhat more close than to that of the Lime Creek. The Amana beds, from evidence secured lately, are apparently the basal member of the Lime

Creek. This member does not crop out in the area where the Lime Creek is best known but appears to the southward, where the later members are either not present or are found only in wells. A preliminary study of the corals and brachiopods of the Amana beds indicates that the fauna is older than that of the Cerro Gordo member of the Lime Creek and intermediate between it and that of the Independence. Six genera of corals in the Amana beds also occur in the Independence. *Zaphrentis* appears to be represented by the same species in each formation. *Tabulophyllum* has one species common to both terranes, but others are distinct. The species of *Macgeea* in the Amana beds is more irregular in shape and apparently is more closely similar to the genotype from the Cerro Gordo member. The species of *Aulocaulis*, *Plexituba* and *Ceratopora* seem to differ sufficiently to be placed in distinct species. Notable absences from the Amana beds are the genera *Syringaxon*, *Metriophyllum*, *Caninia* and *Amplexus*. These are precisely the genera which indicate an early upper Devonian age for the Independence shale.

The Cedar Valley and the Shellrock formations of Iowa are both limestones and, therefore, present different environmental facies from the muddy bottom on which the Independence fauna lived. They also appear to have been due to invasions of seas from the north and northeast instead of from the west, and their faunas, consequently, are not expected to be closely related to that of the Independence. The Cedar Valley fauna is especially prolific in corals, mostly not yet thoroughly studied. Differences are evident in the absence from the Independence of these common Cedar Valley genera: *Hexagonaria*, *Cystiphyllum*, *Diversophyllum*, *Aulacophyllum*, *Ptychophyllum*, *Heliophyllum*, and the tabulate genera of *Favosites*, *Cyathopora*, *Cladopora*, *Syringopora* and *Aulopora*. The presence of *Metriophyllum*, *Zaphrentis*, *Ceratopora*, *Plexituba*, and *Alveolites* in both formations indicates that they are as closely related as is shown by their brachiopods and by their association near the base of the Devonian section of Iowa. Between them they duplicate the characteristic genera of the Frasnian of Europe with fair completeness. With the Shellrock limestone the Independence shale has little in common in its coral fauna with the exception of the genus *Macgeea*.

The great majority of the specimens of corals available for study were collected by the writer. The collection of Dr. Samuel Calvin, though small, is of considerable importance for several reasons. It was secured more than 65 years ago from the shaft sunk in search for coal and from the debris thrown out in its excavation. The shaft passed through the basal Cedar Valley and first brought to notice the shale and its fossils. Calvin in 1878 described the formation and a few of its species. The holotypes of several corals are from this collection as well as paratypes of others. Several small collections of a few specimens each were made later by Dr. A. O. Thomas and Mr. L. P. Elliott from the debris remaining about the trace of the discovery pit and were also used in the study. The Calvin, Thomas, and Elliott material forms part of the University of Iowa collections and was loaned to the writer by the late Dr. Geo. F. Kay and is presently to be returned.

Illustrations of the exteriors of the corals are all of natural size with the few exceptions noted. Those of the longitudinal and transverse sections are enlarged with varying magnifications depending on the sizes of the specimens and the structures to be illustrated. Most of the latter views are photographs of the oiled surfaces of thin and polished sections made by reflected light. Several are by transmitted light to show particular structures in better detail. Retouching of the illustrations has been resorted to in but few instances and then lightly.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA

Class ANTHOZOA

Order TETRACORALLA

No attempt has been made to place these genera into families, as the classification of tetracorals, especially in the family groupings, is somewhat in a state of flux at the present time. The status of some families is rather indefinite, as the exact characteristics of typical genera, such as *Zaphrentis* and *Cyathophyllum*, remain incompletely known.

Genus CANINIA Michelin

Caninia MICHELIN, 1840, in GERVAIS, p. 485.—SMITH, 1935, Jour. Paleontology, vol. 9, no. 1, p. 38.—JEFFORDS, 1943, Jour. Paleontology, vol. 17, no. 6, p. 545 et seq.—EASTON, W. H., 1944, Jour. Paleontology, vol. 18, no. 2, p. 123.

Caninia has recently been discussed by several writers. It is characterized by the generally elongate nature of the corallum, great development of tabulae, dissepimentarium with one or more series of vertically elongate dissepiments, the failure of the major septa to reach the axis in mature stages, the lack of an axial structure and the absence of a cardinal fossula. It is near *Amplexus* but differs in possessing dissepiments. The genotype is from the Mississippian, but species have been reported previously from the Devonian.

The species in the Independence shale is small, with deep calyx and well-developed fossula; the dissepiments appear only in the mature stages; in the immature stages, as seen in axial sections, the interior appears to be similar to that of *Syringaxon*.

CANINIA PRISTINA Stainbrook, n. sp.
Plate 58, figures 10–14; plate 59, figures 7, 8, 10; plate 60, figure 10

Corallum simple, small, conical, expanding rapidly from the apex, with the sides more or less concave, expanding and contracting after the mature diameter has been attained, slightly curved, with apparently the cardinal side concave. Exterior rough generally because of the numerous prominent growth wrinkles or occasional broken calicinal rims exposed during rejuvenation. Epitheca thin, in some instances marked by obscure interseptal ridges and by striae of growth. Measurements of holotype and two paratypes are: height 20.1 mm., 14.8 mm. and 13.2 mm.; diameter 9.1 mm., 11.7 mm. and 11.6 mm.

Calyx circular, deep, in immature examples extending halfway or more toward the apex, shallower in later stages of growth because of development of tabulae; walls steeply sloping, more gently so near center; bottom often flat where a tabula has been recently formed, or concave, smaller in early stages but larger in the gerontic individuals. Septa in two sets, numbering from 40 to 44, smooth along the edges in bottom of calyx but generally papillose or trabeculate above. Major septa strong, complete vertically, extending inward to neighborhood of axis but less so in old specimens. Minor septa short, confined to the calicinal wall, often merely papillose ridges between the major septa. Within the calyx, edges of the developing tabulae and of dissepiments may be seen. A fossula is indicated in mature examples by a depression in the floor of the calyx between the axis and the outer wall; it contains the cardinal septum and may affect the major septa on either side to some extent. Fossula is more prominent in

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EXPLANATION OF PLATE 57

FIGS. *1, 3, 10—Tabulophyllum clinatum* Stainbrook, n. sp. *1, 3,* Anterior and calicinal views of a paratype, M. A. S. 1574, Amana beds, Amana, Iowa. *10,* Calicinal view of the holotype, M. A. S. 940, Brandon, Iowa. (p. 418)

2, 4, 6, 11–13—Ceratopora auletica Stainbrook, n. sp. *2,* Lateral view of the proximal portion of a corallum, a paratype, M. A. S. 946, Brandon, Iowa. *4, 6,* Lateral views of the holotype and a paratype, distal portions of a corallum, Calvin Collection, Independence, Iowa. *11–13,* Lateral views of the distal portions of coralla, M. A. S. 946, Brandon, Iowa. (p. 424)

5, 20—Tabulophyllum dux Stainbrook, n. sp. Calicinal and lateral view of the holotype, a nearly perfect specimen, M. A. S. 937, Brandon, Iowa. (p. 416)

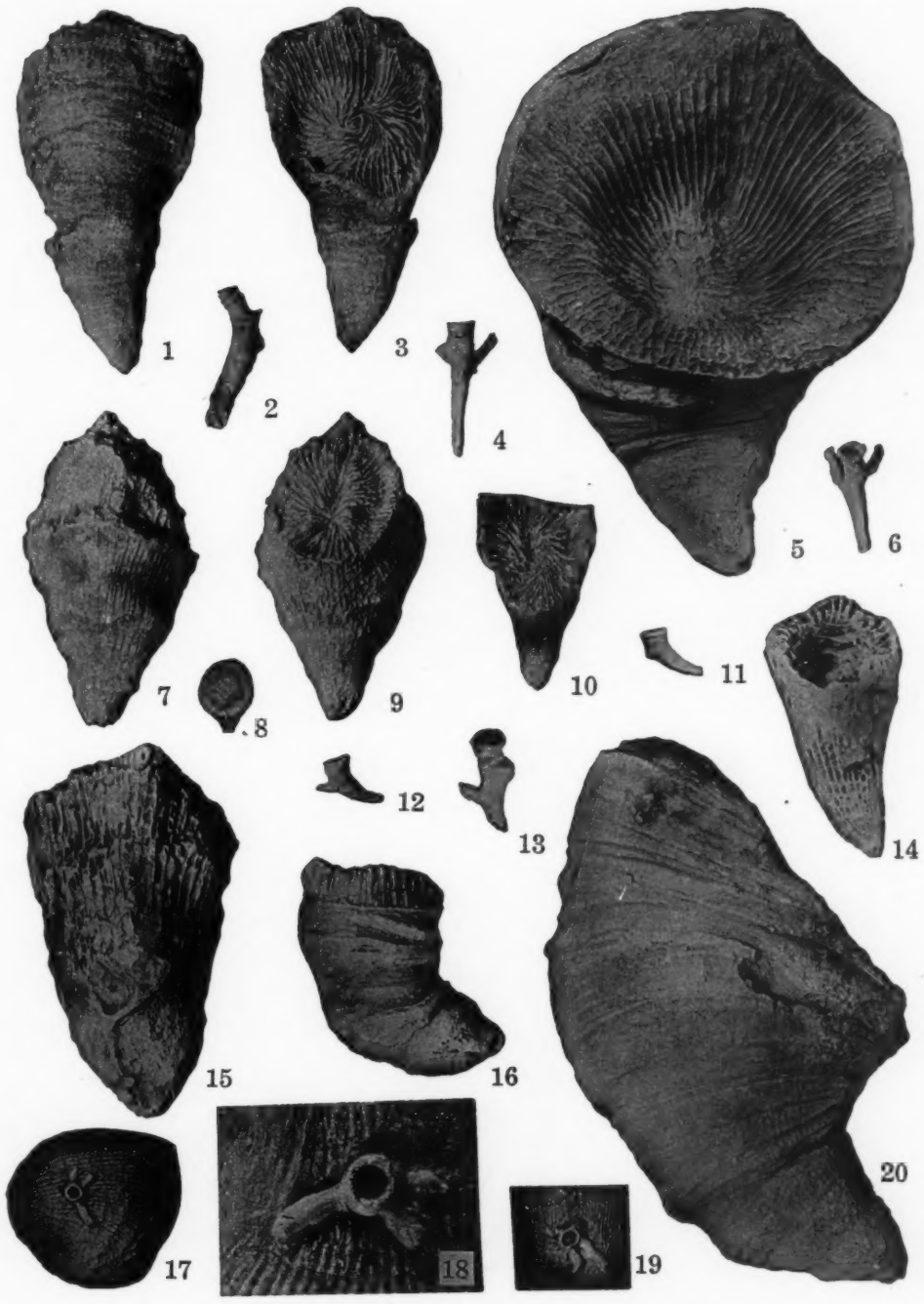
7, 9, 15—Tabulophyllum quadratum Stainbrook, n. sp. *7, 9,* Cardinal and calicinal views of the holotype. *15,* Cardinal view of a large weathered paratype. Both M. A. S. 941, Brandon, Iowa. (p. 418)

8—Macgeea parva Webster. Calicinal view of a hypotype from the discovery pit, Independence, Iowa; Calvin Collection. (p. 421)

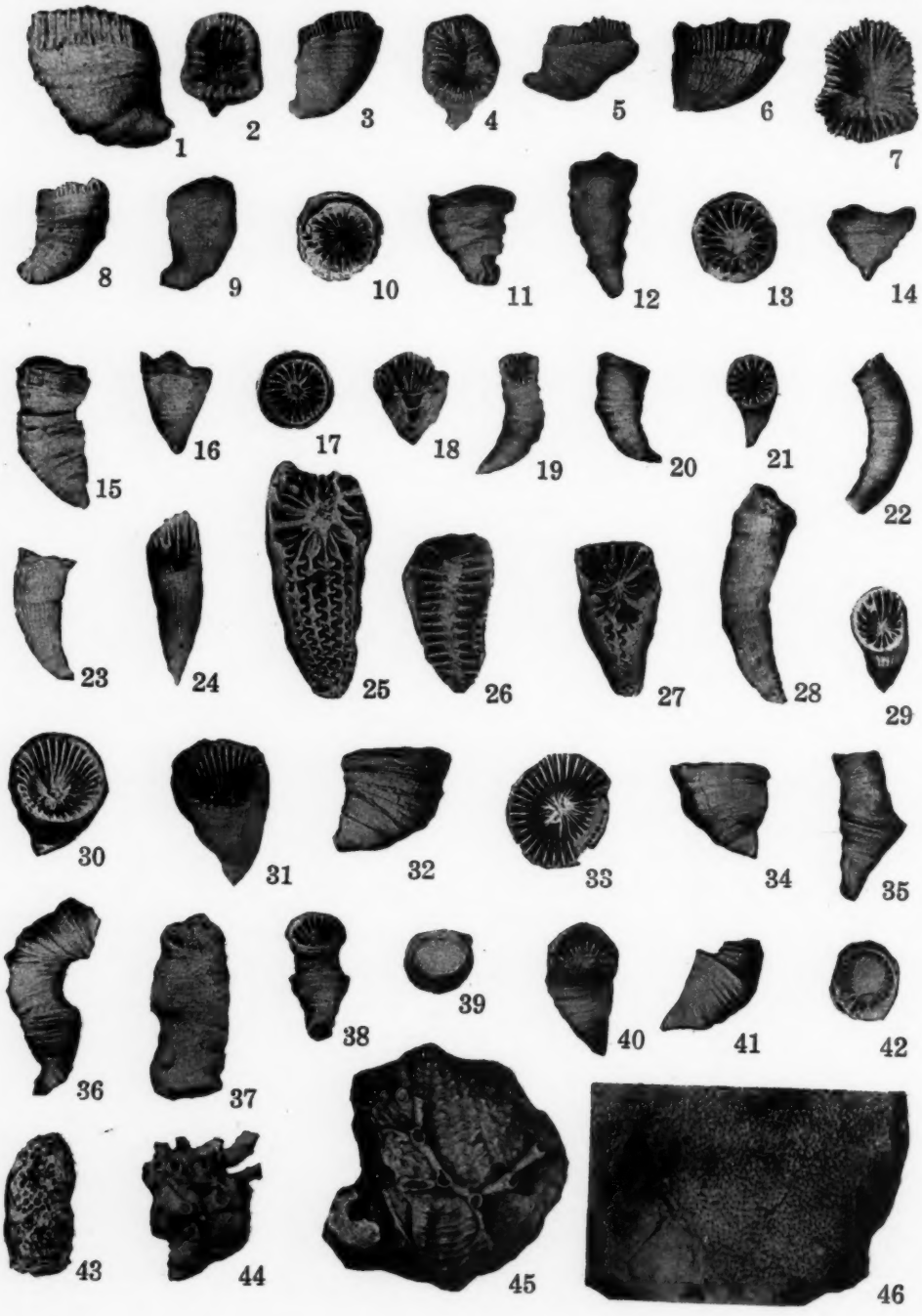
14—Tabulophyllum sp. View of an incomplete example, the only one found, M. A. S. 940, Brandon, Iowa. (p. 416)

16—Macgeea solitaria (Hall and Whitfield). Lateral view of a large nearly perfect hypotype, M. A. S. 1566, Lime Creek shale, Rockford, Iowa. (p. 420)

17–19—Aulocaulis singularis Stainbrook, n. sp. *17,* Calicinal view of the holotype. *18,* Same ×3. *19,* Calicinal view of a paratype. Both M. A. S. 944, Brandon, Iowa. (p. 426)



Stainbrook, Devonian Corals



Stainbrook, Devonian Corals

the immature specimens, in which there may be suggestions of alar fossulae as well. Arrangement of the septa within the calyx of gerontic individuals is almost strictly radial but is progressively more tetrameral in the earlier portions and in young specimens.

Internally in transverse section the tabularium is broad and separated from the narrow dissepimentarium by a nearly continuous inner wall formed by the thickened walls of the inner dissepiments. Major septa extend nearly to the axis and intersect the tabulae which may, however, project uninterrupted into the interseptal loculi to the inner wall. Minor septa short, reaching to or nearly to the inner wall; with major septa generally much thickened with stereoplasm. Dissepiments elongate, thick-walled, usually concave toward the axis.

In longitudiual axial section the tabularium occupies nearly the whole of the interior of the corallum. Tabulae numerous, nearly always horizontal but may be flat, concave or convex, or irregular; usually complete but may extend only part way across the tabularium. In some examples small upwardly convex tabellae may be present centrally. In the apical portion of the holotype and of several paratypes, the tabularium appears to be cylindrical and to resemble the axial tube of *Syringaxon*. Near the level where the mature diameter is reached the tabulae are abruptly expanded toward the outer wall. Dissepimentarium narrow, more prominent in later

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EXPLANATION OF PLATE 58

FIGS. *1–7—Macgeea thomasi* Stainbrook, n. sp. *1*, Lateral view of a large paratype, M. A. S. 931, Brandon, Iowa. *2, 3*, Calicinal and lateral view of a paratype, M. A. S. 807, Brandon, Iowa. *4, 5*, Calicinal and lateral views of a paratype, M. A. S. 931, Brandon, Iowa. *6, 7*, Lateral and calicinal views of the holotype, Calvin collections, from discovery pit, Independence, Iowa. (p. 422)

8, 9—Macgeea parva Webster. Lateral views of two hypotypes, M. A. S. 933, Brandon, Iowa. (p. 421)

10–14—Caninia pristina Stainbrook, n. sp. *10, 11*, Calicinal and lateral views of the holotype. *12*, Lateral view of a paratype. *13, 14*, Calicinal and lateral views of a paratype. All M. A. S. 950, Independence, Iowa. (p. 404)

15–18—Syringaxon calvini Stainbrook, n. sp. *15, 17*, Lateral and calicinal views of the holotype. *16*, Lateral view of a paratype. *18*, Natural longitudinal section of a paratype. All M. A. S. 928, Independence, Iowa. (p. 408)

19–22—Syringaxon independense Stainbrook, n. sp. *19*, Lateral view of a paratype. *20, 21*, Lateral and calicinal views of the holotype. Both M. A. S. 924, Independence, Iowa. *22*, Lateral view of the largest paratype, M. A. S. 923, Brandon, Iowa. (p. 406)

23–29—Metriophyllum iowense Stainbrook, n. sp. *23*, Lateral view of a paratype. *24, 29*, Lateral and calicinal views of the holotype. *25*, Lateral view, ×2, of a weathered paratype showing the uncinate carinae. *26*, Natural longitudinal section, ×2, of a paratype, showing axial structure and umbellate tabulae. *27*, Posterior view, ×2, of a paratype. *28*, Lateral view of the largest paratype. All M. A. S. 919, Independence, Iowa. (p. 410)

30, 31—Charactophyllum praecursor Stainbrook, n. sp. Calicinal and lateral views of the holotype, M.A.S. 953, Brandon, Iowa. (p. 415)

32–34—Zaphrentis praecedens Stainbrook, n. s.p. *32, 33*, Lateral and calicinal views of the holotype, M.A.S. 934, Independence Iowa. *34*, Lateral view of a paratype, M.A.S. 935, Brandon, Iowa. (p. 413)

35–42—Amplexus deeringi Stainbrook, n. sp. *35*, Lateral view of a paratype. *36*, Lateral view of the holotype, Both M.A.S. 927, Independence, Iowa. *37*, Lateral view of a large incomplete paratype, M.A.S. 925, Brandon, Iowa. *38*, Lateral view of a paratype. *39*, Proximal view of a paratype broken to show absence of septa on undersurface of a tabula. Both M.A.S. 927, Independence, Iowa. *40, 41*, Calicinal and lateral views of a paratype, M.A.S. 926, Brandon, Iowa. *42*, Calicinal view of a paratype, M.A.S. 927, Independence, Iowa (p. 409)

43—Thamnopora elliotti Stainbrook, n. sp. View of the holotype. Collected by L. P. Elliott from the discovery pit, Independence, Iowa. (p. 423.)

44, 45—Plexituba contexta Stainbrook, n. gen., n. sp. *44*, View of upper surface of the holotype. *45*, View of a paratype, the corallites not massed as in the holotype. Both M.A.S. 942, Brandon, Iowa. (p. 426)

46—Alveolites cf. *A. rockfordensis* Hall and Whitfield. View of the upper surface of a corallum. M.A.S. 948, Brandon, Iowa. (p. 423)

part of corallum; dissepiments elongate vertically, overlapping slightly so that there may be several in the series. A peripheral longitudinal section shows that the septa extend upward from the apex without interruption.

Caninia pristina in its earlier stages resembles *Syringaxon calvini* and *Amplexus deeringi*, and it is often difficult to separate examples of them without sectioning. *Caninia pristina* is distinguished from the former by differing in shape, having greater calicinal depth, lack of an axial tube, more numerous septa, more irregular exterior, and possession internally of longitudinally elongated dissepiments instead of peripheral tabellae. It is distinguished from *Amplexus deeringi* by the greater diameter attained, presence of minor septa, greater inward extent of the major septa, presence of dissepiments and of more numerous tabulae which do not extend to the outer wall, and vertical continuity of the septa.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype, M.A.S. 950 A; paratypes M.A.S. 950, 951, 952.

Genus SYRINGAXON Lindström

Syringaxon LINDSTRÖM 1882, Ofvers. K. Vetensk-Akad. Forhandl., vol. 39, no. 3, p. 20.—BUTLER, 1935, Geol. Mag., vol. 72, pp. 116–124, pl. 2.—SMITH, 1945, Geol. Soc. America Special Papers no. 59, p. 58.
Laccophyllum SIMPSON, 1900, New York State Mus. Bull. 39, vol. 8, p. 201.

The genus *Syringaxon* was first mentioned by Lindström without written description in a faunal list in which the name *Syringaxon siluriense* (M'Coy), occurs applied to specimens from the Silurian of Gotland. Lindström in 1888 listed the same species as *Lindströmia? siluriensis*. If Lindström's faunal list constitutes an indication, the term *Syringaxon* is the proper name for congeneric species. The distinctive features of the genus have been given by Butler. Two species of corals in the Independence shale agree in most features with *Syringaxon* and are placed therein.

An examination of examples of *Laccophyllum acuminatum* Simpson from the Niagaran of Perry and Decatur Counties, Tennessee, shows that the generic characters of the species agree with those of *Syringaxon* as described by Butler. With it occurs a species of *Enterolasma* with uncinate carinae similar to those seen in *Metriophyllum*. Another species of *Syringaxon* is present in the Haragan shale of Oklahoma with examples of the genotype of *Enterolasma*. Thus two generic types are found in association in a stratigraphic range from the Silurian, the Lower Devonian (Haragan shale of Oklahoma), the Middle Devonian (Hamilton) as represented by *Metriophyllum carinatum* (Simpson) and species of *Barrandeophyllum* and *Alleynia*, and Upper Devonian (Independence shale) as seen in *Metriophyllum iowense* and *Syringaxon independense*.

The structures limited to the interseptal loculi between the inner wall and the epitheca have been designated as tabulae (Butler). They are distinct from the more typical axial tabulae, are formed at higher levels within the corallum, and are independent of each other in adjoining interseptal loculi. Thus their situation is homologous with that of dissepiments but, as pointed out by Hill (1935), the occurrence of the latter is generally dependent on the presence of extended minor septa. In *Syringaxon* these interseptal structures differ from typical dissepiments in being convex outward and in generally sloping downward toward the outer wall. They appear to originate in a manner similar to umbellate tabulae but differ in being discrete and limited to interseptal loculi. They might be termed *peripheral tabellae*.

SYRINGAXON INDEPENDENSE Stainbrook, n. sp.

Plate 58, figures 19–22; plate 59, figure 16; plate 60, figure 12; plate 61, figure 3

Corallum simple, small, conical at first and increasing rapidly in diameter for half the height, cylindrical in later stages of growth, strongly curved in the early portion with the cardinal septum external and generally straight above. Exterior marked by low, broadly rounded interseptal ridges with shallow septal grooves between, and by numerous fine growth lines and strong wrinkles of increment. Measurements of holotype and two paratypes are: length along convex side 20.9 mm., 23.3 mm. and

27.5 mm.; diameter 7.6 mm., 5.6 mm. and 5.7 mm.; height (across curvature) 16.6 mm., 18.7 mm. and 23.7 mm.

Calyx circular, deep, with steeply sloping sides; at bottom in center is a small circular, steep-walled, flat-bottomed pit about one-fourth as broad as the calyx and varying in depth depending on the recency of tabula formation. Septa in two cycles; major septa strong, extending from epitheca to the inner wall, continuous vertically, thin, with smooth axial edges in lower part of the calyx but thicker and trabeculate upward so as to be serrate. Cardinal septum differing slightly from others as it is shorter and does not extend to inner wall, has the septa on either side converging slightly toward it, and is situated in a fossula which may interrupt the continuity of the axial tube. Minor septa alternating with the major ones and appearing as rows of papillose nodes on the calicinal wall. Arrangement of the septa in the calyx nearly radial but typically tetrameral exteriorly on the apical portion of the corallum as revealed by the septal grooves.

In transverse section the septa are distinctly radial and the cardinal septum is seldom distinguishable. Under high magnification each septum appears to be composed of two lamellae of dark material extending inward from the outer wall separately with a distinct space between. About halfway the lamellae approach each other abruptly so that the space between is decreased by half; they maintain this interval inwardly but expand slightly on approaching the axial tube. There one lamella turns toward that from the adjacent septum, which it joins to help form the inner wall. Exceptionally the lamellae of a septum may join each other to form a loop in the wall. Stereoplasm is deposited on the exterior of the septa and on the axial side of the central tube. The outer wall of the corallum is in two layers; the outer layer or epitheca is composed of darker material while the inner portion is composed of distinctly lighter stereoplasm. Minor septa are represented by a pair of short, obscure, discrete, darker lamellae buried in the lighter stereoplasm. The inner wall is generally complete and may be circular or oval.

In longitudinal section between the inner and outer walls the major septa are seen to extend downward from the bottom of the calyx to the apex or to their points of origin above. They are not interrupted by tabellae, of which sections are visible extending from one septum to another but at different levels in the interseptal loculi. In axial section the interior of the corallum is completely divided into two areas by the inner wall. This is a continuous tube from the bottom of the calyx to apex and is about one-half the diameter of the corallum on the average. It appears to be formed by the downturned edges of the central tabulae in conjunction with the septal edges with additional deposition of stereoplasm. Axial tabulae are strong, essentially horizontal but may be convex, flat or concave, and are separated by more or less regular intervals. The tabulae are often considerably thickened and generally extend across the tube; in the upper or later portion the tabulae in some individuals may be incomplete. Apparently the fossula interrupts the continuity of the axial tube, as in some specimens the axial tabulae may extend to the outer wall or may join one of the outer tabellae.

As seen in longitudinal axial and peripheral sections, the peripheral tabellae generally extend from the inner to the outer wall, but in some instances they may not; one may lap onto the subjacent one at some distance from the epitheca. They may be horizontal but usually slope toward the outer wall while others may slope inwardly to the axial tube. They are more variable in shape than the axial tabulae, are generally strongly to weakly convex toward the periphery, but more rarely may be concave or flat. They are more numerous than the central tabulae, less regularly spaced, and three or four may be counted in a space equal to that between two adjacent tabulae. These peripheral tabellae are completely independent of the tabulae and are formed later at a higher level, as is apparent within the calyx. In the area of the cardinal fossula only does an axial tabula extend beyond the tube into the peripheral region and here uncommonly. The tabellae of adjacent interseptal loculi are also independent and show no synchroneity of formation or connection as they occur at different levels; each is limited to its chamber between two septa. In

this respect and in their location they resemble dissepiments and are apparently homologous structures which differ in form. The outer wall is made of a thin epitheca, which shows a number of dark irregular tenuous lamella, vertically elongated, and of an inner thicker layer of stereoplasm lighter in color.

Syringaxon independense resembles *Metriophyllum iowense* Stainbrook in size and shape but is readily distinguished by the absence of an axial column and by the presence of a central calicinal depression formed by the axial tube. The corallum of *Syringaxon independense* is generally more strongly curved toward the apex also.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype, M.A.S. 923 A; paratypes M.A.S. 922–924.

SYRINGAXON CALVINI
Stainbrook, n. sp.
Plate 58, figures 15–18; plate 59, figure 3; plate 60, figure 3, 13; plate 61, figure 4

Corallum simple, small, conical, rapidly expanding from the apex, slightly curved at first, often irregular in growth after mature diameter has been attained. Exterior marked by faint septal grooves and by broadly rounded interseptal ridges. Striae of increment numerous; growth wrinkles common, irregularly spaced and with jagged edges where partial rejuvenation has taken place. Dimensions of holotype and a paratype are: height 18.5 mm. and 12.5 mm.; diameter 11.5 mm. and 10.1 mm.

Calyx circular, deep, the walls sloping steeply from the rim to the nearly flat bottom; in center is a shallow axial pit one-third to one-fourth the diameter of the calyx, rarely more, flat at the bottom, and of variable depth depending on the recency of tabula formation, its wall is circular, usually complete, occasionally interrupted by a fossula. Septa in two sets, about 40 in number; the major average 20, are strong, complete vertically and all extend from the outer wall to the axial tube except for the cardinal septum; their inner edges smooth in bottom of calyx but becoming trabeculate and serrate above; minor septa are small papillose ridges between the others. Septa are radially arranged within calyx but tetrameral in apical portion of the corallum as shown by the septal grooves. A fossula, generally deeper than the axial pit, surrounds the cardinal septum and may connect with the pit axially.

Internally in transverse section the outer wall is thick and composed of a thin, darker outer layer, the epitheca, which has a few dark irregular tenuous lamellae; the inner layer of stereoplasm is thicker and of clearer material without lamellae. The septa are short and heavy; magnified they show two central dark lamellae, which originate at the epitheca and extend to the axial tube, becoming gradually farther apart. At the tube each lamella turns laterally toward that of its neighbor and, by joining it, helps to form this inner wall. Where the septum may be temporarily detached from the inner wall the lamellae may join each other. Between and external to the lamellae is generally a thick deposit of stereoplasm, which may nearly fill the interseptal loculi in some instances. Inner wall thick, generally complete but may be interrupted especially in the vicinity of the cardinal septum, variable in outline, usually circular, and may be nearly half the diameter of the corallum. It is formed by the joining of adjacent septal lamellae and by a thick deposit of stereoplasm. Bars indicating the sections of periaxial tabellae are rare.

In median longitudinal section the corallum is almost completely biareal, as the axial pit of the calyx is continued as a tube to the apex. The wall of the tube is generally complete and may be variable in thickness. Within it are a few tabulae, nine in a corallum 10.9 mm. high, consistently horizontal and flat; some are thickened by a superficial deposit of stereoplasm. Peripheral tabellae generally flat, sometimes convex, generally sloping toward the outer wall, spaced with moderate regularity, and about twice as numerous as the tabulae. They are confined to the interseptal loculi, and those of adjacent loculi are independently developed as shown in sections between the walls. Outer wall as described in transverse section.

Syringaxon calvini differs from *Syringaxon independense* in its larger size, proportion-

ately greater calcinal diameter, more rapidly expanding and less curved apical portion, in having more numerous septa (20 major as opposed to 16), and fewer and more regularly spaced peripheral tabellae.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype M.A.S. 928 A; paratypes M.A.S. 928, 929.

Genus AMPLEXUS Sowerby

Amplexus SOWERBY, 1814, Min. Conch. Great Britain, vol. 1, p. 165.—BUSCH, 1941, Jour. Paleontology, vol. 15, no. 4, p. 397.

The genus *Amplexus* is characterized by its simple elongate corallum, which is cylindrical or alternately contracted and expanded above the initial stage; septa confined to the peripheral portion of the corallum on the upper parts of the tabulae, leaving a central bare area; tabulae numerous, complete, generally extending across the interior and turning downward near the epitheca. The absence of dissepiments is a ready means of separation of members of this genus from *Caninia*.

One species of coral in the Independence shale has all the characters mentioned above but does not have a fossula even in the mature stages.

AMPLEXUS DEERINGI Stainbrook, n. sp.
Plate 58, figures 35–42; plate 59, figures 11, 12

Corallum simple, small, conical, rapidly expanding and slightly curved in the earliest portion, generally irregular in growth above with expansions and contractions and changes in direction of curvature. Epitheca of moderate thickness, much corrugated by numerous, irregularly spaced strong wrinkles of growth. Interseptal ridges faintly developed, generally not apparent, visible in some examples. Dimensions of holotype and two paratypes are: height (through curvature) 26.6 mm., 22.1 mm. and 17.8 mm.; greatest diameter 9.1 mm., 9.5 mm. and 10 mm. Larger dimensions may be attained, as one example is 12.3 mm. in diameter and an incomplete specimen is 25 mm. high (with apical portion missing) and 11.1 mm. in diameter.

Calyx circular, moderately deep, with nearly vertical walls and flat bottom. Septa strong, with apparently smooth edges, decreasing rapidly in height axially and extending from one-third to one-half the distance to the center; consisting of one cycle of major septa numbering 24 in adult examples. No minor septa were detected in the specimens at hand. Septa radially arranged in the calyx and major portion of the corallum but tetrameral in the apical part. Four main septa not distinguishable within calyx; fossula absent.

Internally the tabulae are the dominant structures. They are moderately strong, complete, generally horizontal and plane but occasionally slightly concave or convex. In most instances they extend across the corallum but some may be incomplete and only reach to the center. In some examples the tabulae are regularly spaced so that one 20 mm. high shows 12 tabulae. Another of the same height has 15 complete tabulae and several incomplete ones. Several gerontic specimens have the tabulae distinctly thin and closely spaced. In a peripheral vertical section the septa are generated successively on every tabula. Natural sections show that the under surface of the tabulae are devoid of septa and have radial depressions indicating the positions of the septa on the upper surfaces. An occasional tabula may be very short and slope from the outer wall down to the subjacent one. Other structures absent or unobserved.

Immature examples of *Amplexus deeringi* are not readily distinguished from specimens of *Syringaxon calvini*. The presence of a fossula, of minor septa, and of trabeculate major septa in the latter usually suffices to separate them, but in some instances a longitudinal section is necessary.

Amplexus deeringi does not differ greatly in shape from *Amplexus hamiltoniae* Hall but averages smaller. The interseptal ridges are much more apparent in the latter, and its tabulae appear to bend downward more consistently near the outer wall.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype, M.A.S. 927 w; paratypes, M.A.S. 925, 926, 927.

Genus METRIOPHYLLUM Milne-Edwards and Haime

Metriophyllum MILNE-EDWARDS AND HAIME, 1850, Monographie des polypiers fossiles des terrains palaeozoiques, t. 5, p. 317.—SMITH, 1945, Geol. Soc. America Special Papers no. 59, p. 28.

Generic diagnosis and a description of the genotype, *Metriophyllum bouchardi* Milne-Edwards and Haime, have been given recently by Smith. Our species from the Independence shale agrees in all essential generic details and is confidently placed in the genus. It is one of the most common and characteristic fossils of the formation.

Metriophyllum bouchardi occurs in the Upper Devonian, Frasnian, at Ferques near Boulogne, France, with *Macgeea gallica* Lang and Smith and *Phillipsastrea boloniense* (Milne-Edwards and Haime). In this hemisphere the genus is represented in the Tully limestone of New York by *Lopholasma tullium* Williams and in the Olentangy shale of Ohio by *Lopholasma delawarensis* Baker. In Iowa a species is present in the Cedar Valley limestone but none is known in the Shellrock and Lime Creek formations above. In the Independence shale the genus is accompanied by representatives of *Macgeea* and *Hypothyridina*, an association also present in the Frasnian and one which emphasizes the lower Upper Devonian age of the shale.

Smith has pointed out that *Lopholasma carinatum*, genotype of *Lopholasma* Simpson (1900), is congeneric with *Metriophyllum bouchardi*, and the name thus becomes a synonym. However, Smith stated that *Lopholasma carinatum* Simpson and *Stereolasma rectum* (Hall) are conspecific. In a study made of *Stereolasma rectum*, no uncinate carinae similar to those of *Metriophyllum* were discovered by the writer in either axial or peripheral longitudinal sections. None was mentioned by Busch (1941) and none appears in his sections of *Stereolasma*. It would appear with the absence of these important structures that *Stereolasma rectum* (Hall) is not congeneric with *Metriophyllum carinatum* (Simpson). *Metriophyllum* sp. A, described by Smith, also lacks these carinae and as in addition it has a hollow axial structure we would question that it is a true member of the genus. *Lopholasma carinatum* Simpson is stated by its author to come from the Hamilton shales, western New York. If correct, the range of *Metriophyllum* is then extended into Middle Devonian.

Examples of *Enterolasma strictum* (Hall) from the Haragan shale of Oklahoma also show uncinate carinae similar to those of *Metriophyllum*, as does a Silurian form from Tennessee. *Enterolasma* may then be ancestral to *Metriophyllum*.

METRIOPHYLLUM IOWENSE
Stainbrook, n. sp.
Plate 58, figures 23–29; plate 59, figures 2, 17; plate 60, figures 2, 7

Corallum simple, small, conical, gently expanding from the acute apex and slightly curved with the cardinal septum on the convex side. Exterior somewhat irregular, with growth wrinkles common and strong enough occasionally to interrupt the continuity of the interseptal ridges. Growth generally regular, with the diameter increasing with moderate rapidity to the place where the last major septal increase occurs, thence enlarging slightly or not at all in breadth. A few examples display considerable irregularity in direction of growth. Epitheca well developed, thick in later portions of corallum, marked externally by numerous fine, crowded, transverse striae and by strong interseptal ridges. Dimensions of holotype and two paratypes are: length along convex side 24.9 mm., 34.1 mm. and 21.1 mm.; greatest diameter 8.1 mm., 9.1 mm. and 7.2 mm.; depth of calyx 8.1 mm., 7.5 mm. and 8.1 mm.

Calyx circular in outline, deep, varying from a third of the length in an immature corallum to a fifth in a large one; sides almost vertical, with bottom broad, flat or slightly depressed centrally in some specimens. No fossula is present in the adult stages, and no definite central structure appears in the calyx other than the union of the septal edges to form a small dense axis. This is usually flat in most examples but may be a little depressed below the floor of the calyx. Septa in two sets; major septa strong, complete, extending from the epitheca to axis, lamellose and smooth-edged in the bottom of the calyx and for a short

way up the sides, gradually becoming stouter, broader, rough and serrate on approaching the rim of the calyx. The septal serrations are larger near the top and appear to be due to trabeculae as these portions of the septa are more recent, less extended, and less developed. Minor septa appear as low papillose ridges on the calicinal wall between the major septa. They are larger and more strongly trabeculate distally and decrease in height and width toward the bottom of the calyx. In some instances these septa may be indicated only by a linear series of small nodes; apparently they are absent in some specimens. On the exterior, however, there is always a distinct septal groove for each minor septum whether or not it is apparent within the calyx. The major septal number is 16 in mature specimens, and all have appeared where the growth of the corallum is about one-third advanced in height; minor septa number the same. Arrangement of the septa in the calyx is strictly radial, and the four main septa are indistinguishable either in size or by position therein. In the apical portion of the corallum the tetrameral arrangement is readily apparent from a study of the interseptal ridges but becomes radial when the average diameter is attained.

Internally the corallum is not divided into tabularium and dissepimentarium, as dissepiments are absent. An axial column occupies the central part and extends from the apex to the bottom of the calyx, in which it makes no projection. In natural and artificial longitudinal sections it appears as a dense rod about one-fifth the diameter of the corallum. This axial column is formed by the joined inner edges of the major septa in conjunction with the axial portions of the uncinate carinae with additional deposits of stereoplasm. In transverse section the septa extend to the axis and show that there is no separate axial structure. In longitudinal section the axial column seems to be composed of vertical elements—the darker lamellose parts of the septa—which undulate considerably in their upward courses. Much of this is due to the influence of the carinae, which alternately join the column. No cavity within this structure was seen in any specimen sectioned.

Besides the septa and the axial pillar the other prominent structures are the carinae. They are thick curved plates, which extend from the epitheca to the axis with one edge attached to a septum. Generally they are horizontal or apparently were horizontal when the calyx was horizontally disposed during the growth of the corallum. They occur at regularly spaced intervals of about 0.5 mm.; those on each side of a septum alternating slightly, rarely they may be opposite. Each carina projects laterally across the interseptal loculus nearly to the adjacent septum but never touches it except in forming the axial column. The carinae of one side of a septum alternate with those of the adjacent septum in an interlocking manner. Each curves outward and upward in the interseptal loculus and appears as a characteristic spurlike projection when the epitheca is absent or removed.

These carinae are quite different from those in *Heliophyllum*, especially in usually having a horizontal position instead of being strongly slanted from the axis to the epitheca; some even slope slightly downward toward the axis instead. The carinae of *Metriophyllum* also seldom if ever appear on the edges of the septa within the calyx, and their strength is remarkable, as they far outweigh the tabulae in importance as internal skeletal structures. Lastly their characteristic outward and upward curvature is a distinct difference. So outstanding are the features of this type of carinae in *Metriophyllum* that it seems that they should be designated by a distinctive term, *uncinate carinae*, from their appearance when the epitheca is absent.

The tabulae are relatively sparse and generally confined to the middle portion of the corallum. Apparently they are nearly absent in the lower one-third and hence rarely occur in immature individuals; none is seen in the calyx. They are thin, tenuous, and extend downward and outward from the axial column at intervals of 0.25 to 0.5 mm. Some extend from one uncinate carina to the adjacent one, others extend across two or three intercarinal spaces. On a decorticated example the tabulae extend as a rule from the distal edges of the carinae downward or upward to the immediate alternating carinae. As they differ from the typical axial horizontal tabulae they may

be differentiated as the *umbellate tabulae.*

In transverse section the outer wall is thick and seems to be formed by two types of calcareous tissue. Externally there is a layer, the epitheca, variable in thickness, of light material with several undulatory tenuous darker laminae. The inner portion, sometimes the thicker, apparently is formed of stereoplasm in which the minor septa are embedded. Its calcareous fibers loop around the walls of the interseptal loculi, the minor septa and along the sides of the major septa. The latter may undulate slightly or curve a little in extending from the outer wall to the axis. Each, highly magnified, appears to be formed of two dark lamellae with lighter stereoplasm between and external. Peripherally these lamellae disappear and blend with the stereoplasm of the inner layer of the outer wall; axially they spread laterally and join those from the adjacent septa and aid in forming the axial column. Each minor septum seemingly has one central dark lamella and the calcareous fibres of the stereoplasm around its apex toward the axis. The bars in the interseptal loculi, representing the sections of the tabulae, are generally concave toward the outer wall.

In longitudinal sections the epithecal portions of the outer wall shows a number of dark irregular vertical laminae with clearer tissue between. Depending on the angle of the section the uncinate carinae may extend from the wall to the axial column or may appear as spines projecting outward from wall or column.

Metriophyllum iowense differs from *Metriophyllum bouchardi* Milne-Edwards and Haime, the genotype, in being larger, more curved and slightly less thick. It also has fewer septa on the average, 16 major as opposed to the 22–24 noted by Milne-Edwards and Haime. It is about twice as high as *Metriophyllum tullium* (Williams), a little thicker, has fewer major septa, 16 as against 20 for the latter, and the uncinate carinae appear to be more numerous, heavier and more curved distally. *Metriophyllum iowense* is about twice as high as *Metriophyllum delawarense* (Baker), is comparatively thinner, has 16 major septa instead of 12, and its

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EXPLANATION OF PLATE 59

FIGS. *1, 6—Ceratopora auletica* Stainbrook, n. sp. *1,* Longitudinal section, ×10, of a paratype. *6,* Longitudinal section, ×7, of the distal portion of a corallite showing calyx, branch, internal cysts and wall structure. Both M.A.S. 946, Brandon, Iowa. (p. 424)

2, 17—Metriophyllum iowense Stainbrook, n. sp. *2,* Longitudinal section, ×2, of a paratype. *17,* Transverse section, ×7, of a paratype. Both M. A. S. 921, Brandon, Iowa. (p. 410)

3—Syringaxon calvini Stainbrook, n. sp. Calicinal view of a paratype, M. A. S. 928, Independence, Iowa. (p. 408)

4, 9—Plexituba contexta Stainbrook, n. sp. *4,* Transverse section of a basal corallite of the holotype, ×5, showing edges of internal cysts. *9,* Transverse section of a corallite ×6, showing wall lamellae. Both M. A. S. 935, Brandon, Iowa. (p. 426)

5—Zaphrentis praecedens Stainbrook, n. sp. Transverse section, ×1.5, of a paratype, M. A. S. 935, Brandon, Iowa. (p. 413)

7, 8, 10—Caninia pristina Stainbrook, n. sp. *7,* Longitudinal section, ×2, of a paratype, M. A. S. 950, Independence, Iowa. *8,* Longitudinal section, ×2, of a paratype, M. A. S. 951, Brandon, Iowa. *10,* Longitudinal section, ×2, of a paratype, M. A. S. 950, Independence, Iowa. The abrupt expansion of the tabulae in the early part of the corallum and the central tube of the apical portion are well shown. (p. 404)

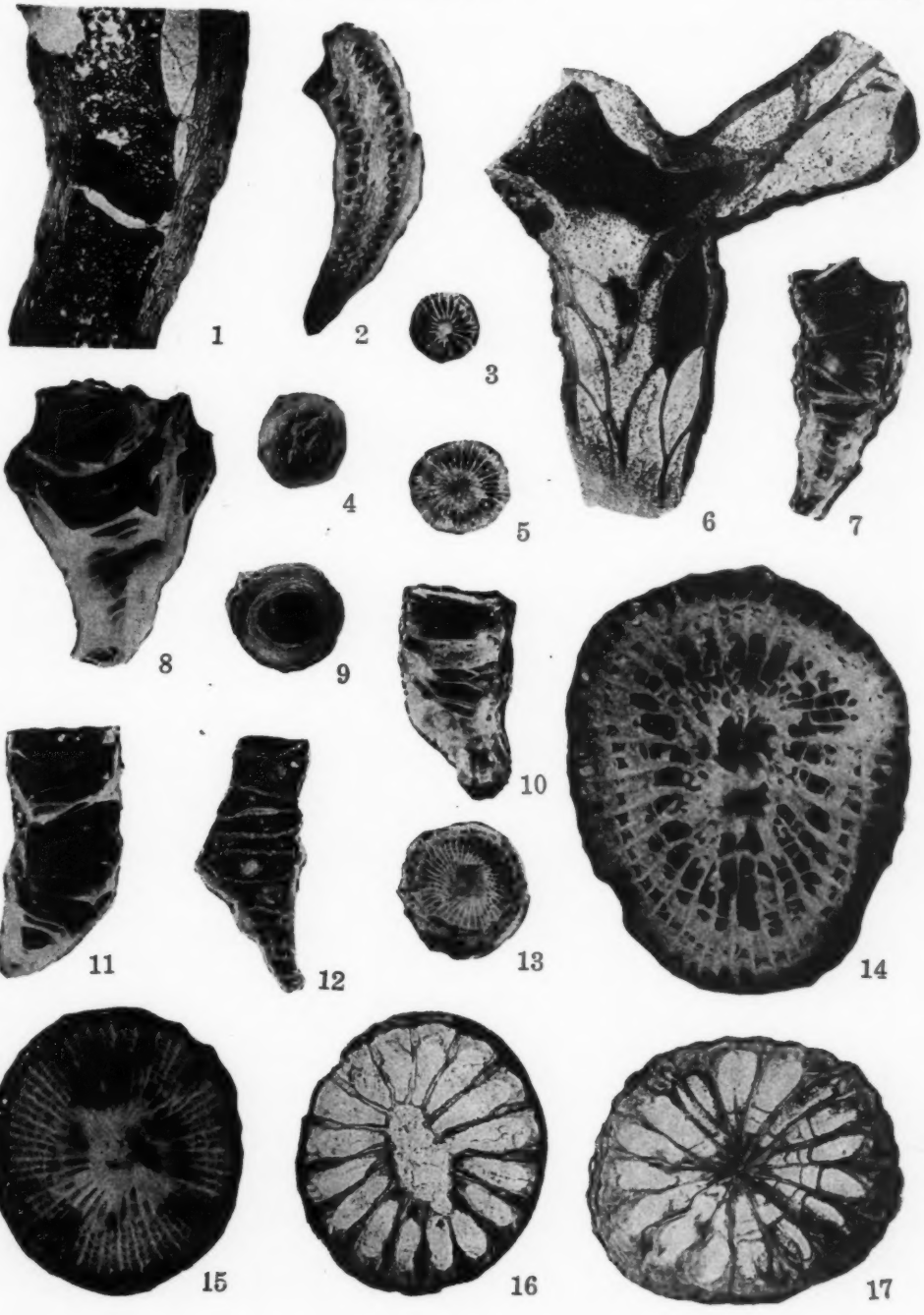
11, 12—Amplexus deeringi Stainbrook, n. sp. Longitudinal sections ×2, of two paratypes, M. A. S. 925, Brandon, Iowa and 927, Independence, Iowa. (p. 409)

13—Tabulophyllum dux Stainbrook, n. sp. Transverse section of the early portion of a paratype, M. A. S. 938, Brandon, Iowa. (p. 416)

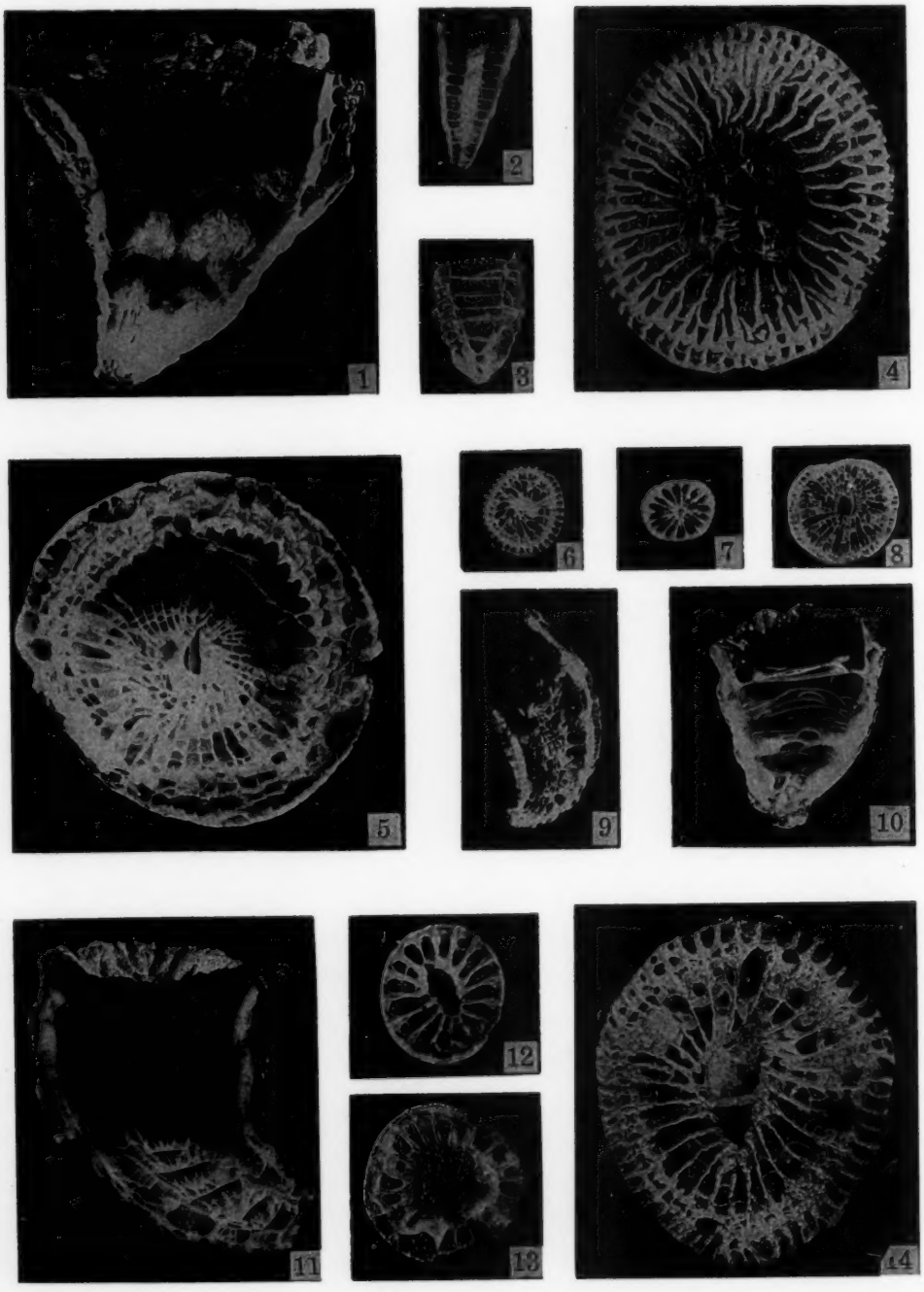
14—Macgeea thomasi Stainbrook, n. sp. Transverse section, ×4, of a paratype, M. A. S. 807, Brandon, Iowa. (p. 422)

15—"Heliophyllum" solidum (Hall and Whitfield). Transverse section, ×2, of a specimen from the Lime Creek shale, Rockford, Iowa. For comparison with *Charactophyllum;* shows absence of crossbar carinae of *Heliophyllum* and species may be referable to *Microphyllum.* (p. 415)

16—Syringaxon independense Stainbrook, n. sp. Transverse section, ×7, of a paratype, M. A. S. 922, Brandon, Iowa. The two lamellae of the major septa and their separation near the epitheca apparent. (p. 406)



Stainbrook, Devonian Corals



Stainbrook, Devonian Corals

uncinate carinae are stouter, more numerous and more extended laterally.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype, M.A.S. 919 A; paratypes, M.A.S. 919–921.

Genus ZAPHRENTIS Rafinesque and Clifford

Zaphrentis (*Zaphrenthis*) RAFINESQUE AND CLIFFORD, 1820, Ann. Gener. Sci. Phys. Bruxelles.

The genotype, *Zaphrentis phrygia* Rafinesque and Clifford, occurs in the Jeffersonville limestone at the Falls on the Ohio. Numerous examples secured there and apparently of this species, as recognized by authors generally, are at hand. They are characterized by the short, curved, broadly conical, simple corallum with deep calyx, numerous septa tetramerally arranged and cardinal fossula. The septa within the calyx are serrate above the bottom and appear to be carinate at first glance. However, the small ridges on the sides of the septa may possibly not be true carinae, as transverse sections of the calicinal wall show that there are no crossbar carinae projecting into the interseptal loculi. Bars in the cross sections extending from one septum to an adjacent one are edges of dissepiments. The small external ridges on the septa resembling carinae in the calyx appear to be either trabeculae or incipient dissepimental structures. Several species in the Devonian strata of Iowa which similarly appear to have carinate septa do not have cross-bar carinae in cross and longitudinal sections.

On the other hand all specimens studied by the writer are silicified and leave much to be desired in working out the internal structures. Examples of *Zaphrentis phrygia* preserved as calcium carbonate might show cross-bar carinae. Further study seems to be needed to determine the true nature of *Zaphrentis*, especially the nature and number of dissepiments and tabulae. It is also pointed out that the presence of ridges on the sides of the septa within the calyx does not necessarily indicate the presence of carinae in sections.

Our specimens from the Independence shale, although smaller, agree in nearly all particulars with the genotype, especially in the characteristically serrate septa with lateral ridges giving them a carinate appearance. Sections, transverse and longitudinal, of the calicinal wall above the bottom of the calyx show no carinae in the interseptal loculi. As in *Zaphrentis phrygia* the edges of the septa of our form are smooth in the bottom part of the calyx.

ZAPHRENTIS PRAECEDENS Stainbrook, n. sp.

Plate 58, figures 32–34; plate 59, figure 5; plate 61, figure 7

Corallum simple, small, conical, curved at first, tending to become straighter in

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EXPLANATION OF PLATE 60

FIGS. *1, 5—Tabulophyllum dux* Stainbrook, n. sp. *1*, Longitudinal section, ×1.5, of a paratype. *5*, Transverse section, ×2.5, of a paratype. Both M. A. S. 938, Brandon, Iowa. (p. 416)

2, 7—Metriophyllum iowense Stainbrook, n. sp. *2*, Longitudinal section ×2, of a paratype; uncinate carinae, umbellate tabulae and axial column well shown. *7*, Transverse section ×2, of a paratype. Both M. A. S. 921, Brandon, Iowa. (p. 410)

3, 13—Syringaxon calvini Stainbrook, n. sp. *3*, Longitudinal section, ×2, of a paratype. *13*, Transverse section, ×3, of a paratype. Both M. A. S. 928, Independence, Iowa. (p. 408)

4—Charactophyllum nanum (Hall and Whitfield). Transverse section, ×2, of a hypotype from the Lime Creek shales, Rockford, Iowa. Absence of crossbar carinae is apparent. (p. 415)

6, 9—Macgeea parva Webster. *6*, Transverse section, ×2, of a mature hypotype. *9*, Longitudinal section, ×2, of a hypotype. Both M. A. S. 932, Brandon, Iowa. (p. 421)

8—Charactophyllum praecursor Stainbrook, n. sp. Transverse section, ×2, of a paratype, M. A. S. 953, Brandon, Iowa. (p. 415)

10—Caninia pristina Stainbrook, n. sp. Longitudinal section, ×2, of a paratype, M. A. S. 950, Independence, Iowa. (p. 404)

11, 14—Macgeea solitaria (Hall and Whitfield), *11*, Longitudinal section, ×2, and transverse section, ×2, of two hypotypes, M. A. S. 1566, Lime Creek shales, Rockford, Iowa (p. 420)

12—Syringaxon independense Stainbrook, n. sp. Transverse section, ×3, of a paratype, M. A. S. 922, Brandon, Iowa. (p. 406)

maturity. Exterior somewhat rough and irregular due to numerous heavy growth wrinkles. Epitheca thin, complete, marked by faint interseptal ridges and numerous fine growth lines. Measurements of holotype and two paratypes are: height (with rim of calyx horizontal) 13.1 mm., 17.1 mm. and 13.7 mm.; length of convex side 24.1 mm., 28.1 mm. and 25.1 mm.; greatest diameter 15.7 mm., 17.2 mm. and 16.9 mm.

Calyx circular if not distorted by pressure after burial, deep, extending halfway to apex in mature examples or three-fourths of way in youthful specimens; walls nearly vertical, joining floor abruptly at nearly right angles; bottom broad, nearly flat, depressed peripherally and centrally. Septa strong, numbering about 64 in maturity, in two sets; major septa projecting 1 or 2 mm. from calicinal wall into calyx and extending to or nearly to the axis, where they tend to twist slightly; minor septa confined to inner side of outer wall, often appearing as linear series of spines, extending inward a millimeter or two below the floor of calyx. All septa have strongly serrate edges from the rim to the bottom of calyx but are smooth there; serrations are due to trabeculae, which curve upward and inward toward the outer wall giving the septa a ridged appearance. These lateral ridges on the sides of the septa in the calyx may be mistaken for carinae, which are absent as shown by sections and broken specimens revealing the interior. In the neanic stages the septa are strongly tetrameral in the calyx and exteriorly. In maturity with increase in numbers and with appearance of the minor septa, the arrangement becomes more nearly radial. Some of the major septa fail to reach the center and tend to become arranged in groups of variable and alternating length. The four main septa are no larger than the other of the major set: the cardinal is generally smaller, with those on either side converging toward it. Usually the cardinal and counter septa join to form a complete septum across the calicinal floor.

Internally the tabularium is large and comprises the major portion of the corallum. In transverse section the major septa reach the axis or nearly so and may be slightly thickened there. Sometimes a small axial space may be devoid of septa in some parts of the corallum. Dissepiments are thickened and may form a dense zone near the outer wall. All septa are considerably thickened by stereoplasm within the dissepimentarium. Outer wall has a thin external layer, the epitheca, with several tenuous darker lamellae and a thick inner layer of structureless stereoplasm. Each septum, when magnified, appears as composed of two dark lamellae with lighter material between.

In longitudinal axial section the tabulae are strong, numerous and irregular. They may be convex or flat axially, convex outwardly, and bent downward beyond and peripherally concave, especially near the cardinal septum. Boundary between the dissepimentarium and the tabularium not distinct, distinguished chiefly by the cessation of dissepiments and by the axial ending of the minor septa. Dissepimentarium narrow, widest in the upper part of the corallum and showing several series of dissepiments, but only one row apically. Dissepiments thin, small, arching inwardly and downwardly.

Mature specimens of *Zaphrentis praecedens* resemble immature examples of *Zaphrentis solida* Hall and Whitfield and mixtures would be difficult to separate. Mature individuals of the latter species attain heights three to four times that of the former and diameters from two to two and a half as much. *Zaphrentis solida* has a much shallower calyx proportionately and a larger number of septa therein. In transverse sections the minor septa extended farther inward and the dissepimentarium is proportionately broader in *Zaphrentis solida;* the dissepiments also inosculate, are more abundant, crowded and irregular. *Zaphrentis praecedens* may be ancestral to *Zaphrentis solida*. Fenton and Fenton (1937) placed the latter in the genus *Heliophyllum*, but the absence of true cross-barred carinae removes it from that genus. The serrations on the septa resembling carinae are formed by trabeculae.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype, M. A. S. 934 A; paratypes, M. A. S. 934–936, two specimens in the Calvin Collection, S. U. I.

Genus CHARACTOPHYLLUM Simpson

Charactophyllum SIMPSON, 1900, New York State Museum Bull. 39, vol. 8, pp. 209–10.—FENTON, AND FENTON, 1924, Michigan Univ. Mus. Geology Contr., vol. 1, p. 25.—SMITH, 1945, Geol. Soc. America Special Papers no. 59, p. 17.

The genotype of *Charactophyllum* is given by Simpson as *Campopyllum nanum* Hall and Whitfield and reference made to "23 Ann. rep't N. Y. state mus. nat. hist." The horizon to which Simpson referred this species, "Lower Carbonic, Rockford, Ind.," must be in error as most of the species described in the article by Hall and Whitfield came from Rockford, Iowa, and are Upper Devonian in age. Simpson's generic diagnosis is very brief, about the only definite character mentioned being the septa with sides "carinated, the carinations forming serrations or denticulations on the margins of the septa." The Fentons and Smith have also given brief summaries of its generic features. They are, in the main, the elongate-cylindrical shape of the simple corallum, d_ep calyx, numerous septa in alternating sets which leave a clear space about the axis, numerous tabulae and dissepiments. The septa within the calyx appear to be carinated, but the small ridges on their sides are not typical carinae similar to those of *Heliophyllum*. These ridges do not project into the interseptal loculi and are not evident in transverse and longitudinal sections. (See plate 60, figure 4.) The septa are serrate along the edge and the ridges on the sides are due to trabeculae. The septa may be said to be trabeculate rather than carinate.

Ma (1943) has referred *Charactophyllum nanum* (Hall and Whitfield) to the genus *Heliophyllum*, but the lack of the characteristic carinae of that genus and the internal differences in the length and appearance of the septa seem sufficient to prohibit this generic placement. Smith considers *Charactophyllum* as a separate genus.

Our species is small but shows the main features of *Charactophyllum*, especially in the axial shortening of the major septa and in the presence of trabeculae on the septa. It is apparently ancestral to the Lime Creek form.

CHARACTOPHYLLUM PRAECURSOR Stainbrook, n. sp.

Plate 58, figures 30, 31; plate 60, figure 8; plate 61, figure 8

Corallum simple, small, conical, expanding with moderate rapidity from the apex nearly to the calicinal rim, curved, with cardinal side convex. Exterior marked by a few large broad, low growth wrinkles. Epitheca thin, generally worn away in many places, the septal grooves faint. Measurements of holotype and a paratype are: height (with calyx horizontal) 12.8 mm. and 15.4 mm.; length of convex side 23.1 mm. and 28.6 mm. (incomplete); length of concave side 14.6 mm. and 14.8 mm. (incomplete); diameter 13.6 mm. and 15.7 mm.

Calyx circular, deep, extending about one-third the distance to the apex; walls thick, steeply sloping; bottom broad, more than half diameter of calyx, nearly flat, with a small axial depression. A fossula with the cardinal septuma borted at bottom of calyx extends from the axis to the wall. Septa well developed, numbering about 62, in two sets. Major septa large, projecting inward from the calicinal wall, extending along the bottom to the edge of the axial pit; their edges smooth in bottom of calyx but thicker, serrate and strongly trabeculate in upper part. Minor septa small, limited to the calicinal wall, generally appearing in calyx as low papillose or spinose ridges. Septal arrangement within calyx is radial except near the cardinal septum, which is distinguished by its brevity; on exterior apically it is distinctly tetrameral.

Internally in transverse section the boundary between the tabularium and the dissepimentarium is not distinct. The tabulae appear as short outwardly convex bars between the septa. The outer wall, as revealed by high magnification, consists of a thin epitheca formed of alternating tenuous lamellae of light and dark material, and a thicker inner layer of stereoplasm. The major septa extend nearly to the axis but leave a central open space; their inner ends are slightly expanded but apparently do not form a wall there. Minor septa extend inward a short way beyond the inner wall. The septa are thickened distally near the

outer wall and appear, when magnified, to be composed of two thin dark lamellae with clear material between. A continuous inner wall is formed by the deposition of stereoplasm and the thickening of the septa and dissepiments a little distal to the axial ends of the minor septa.

In longitudinal section the tabularium is confined to the axial portion of the corallum, which is free from septa and is about one-third its diameter; the outer boundary is not distinct but is chiefly marked by the meeting of the tabulae and dissepiments. The tabulae are somewhat irregular, generally horizontal and gently convex, occasionally crowded and thickened, sometimes tabellate centrally, and with edges turned downward peripherally. The dissepimentarium is separated into two areas by the inner wall, which appears as a heavy deposit of stereoplasm near the outer wall. The dissepiments external to it are small and nearly as broad as long. The dissepiments within are large, very irregular in size and arrangement; generally they are convex inward and may be elongated parallel to the axis. Sections of the septa show the trabeculae; those near the calicinal rim are generally directed inward and downward, a tendency at variance with carinae which apparently are absent in this species.

Charactophyllum praecursor is very similar to *Zaphrentis praecedens* but is distinguished by its shallower calyx, by the presence of the axial pit, by the fewer and thicker dissepiments, which have a much less horizontal extent. The small size readily distinguishes it from *Charactophyllum nanum* (Hall and Whitfield) of the Lime Creek beds.

Occurrence: Independence shale at Brandon, Iowa.

Types: Holotype, M.A.S. 953 A; paratypes 953, 954.

Genus TABULOPHYLLUM Fenton and Fenton

Tabulophyllum FENTON AND FENTON, 1925, Michigan Univ. Pub. no. 1, p. 30.—SMITH, 1945, Geol. Soc. America Special Papers no. 59, p. 58.

The genus *Tabulophyllum* is well represented in the Iowa Devonian and three species are recognized in the Independence shale. Among its distinctive characteristics are the general robustness of the coralla, numerous septa and abundant tabulae; in some species the corallum may be laterally compressed, but this feature is not seen in Independence forms. Perhaps most distinctive of the genus is the development within the dissepimentarium of large cystosepiments, which may interrupt several septa. The cystosepiments form a notable peripheral zone and may cause a characteristic type of weathering. Another feature not previously mentioned is the presence of porelike structures, which appear in sections as cylinders of darker material in the dense white epitheca. On the exterior they appear as dark subcircular structures, more commonly present in the septal grooves but occurring also on the interseptal ridges, sometimes in vertical linear series or in horizontal ones. In some worn examples the structures may be actual porelike pits. They have been observed in examples of *Tabulophyllum* from the Lime Creek beds, including the genotype, and have been found of value in the recognition of the generic position of questionable examples of similar forms.

TABULOPHYLLUM DUX Stainbrook, n. sp.
Plate 57, figures 5, 20; plate 59, figure 13; plate 60, figures 1, 5

Corallum simple, large, conical, expanding with moderate rapidity from the apex, curved with the anterior side convex, and may be slightly irregular in growth and rate of increase. Exterior somewhat rugose, smooth in the earlier portion, flexed in later part by numerous large growth wrinkles; growth striae few. Epitheca thin, marked by low indistinct interseptal ridges. Measurements of holotype and a paratype: height (calyx horizontal) 45.5 mm. and 75 mm.; length of anterior side 109.7 mm. and 127 mm.; length of posterior side 36.9 mm. and 81 mm.; diameter of calyx 58.4 mm. and 54.6 mm.

In the epitheca of well-preserved specimens numerous porelike structures are visible under magnification The pores appear to be filled with dark material, which contrasts with the hard white calcium carbonate around them. They are roughly circular and generally are concentrated in the

septal furrows but may occur on the interseptal ridges as well but less commonly. They are somewhat irregularly distributed but may form one or two linear series parallel to the septa or transverse series along a growth line. Ten have been observed in a square millimeter. In longitudinal section they apparently traverse the outer wall perpendicular to the exterior surface, maintain the same diameter and extend to or nearly to the inner surface of the epitheca. They were first observed in specimens of the genus from the Independence shale but were found to occur on examination in examples of several species in the Lime Creek shale. The pores may not have been actual openings in the epitheca and may have been due to peculiar variations in the formation of the epitheca. This character has been found useful in identifying members of the genus.

Calyx capacious, generally circular, deep, extending downward about one-third the distance to apex in medium-sized individuals; walls thick, sloping steeply to abruptly; bottom ranging from one-third to one-half the diameter, nearly flat, slightly elevated centrally, depressed peripherally. Cardinal fossula well developed, extending from near axis to calicinal rim, deeper at bottom of calyx. Septa number about 120 in holotype, in two sets which alternate. Major septa strong, thin, laminar, projecting into calyx from walls and extending to or nearly to axis, where they twist more or less. Minor septa small, low, extending from rim nearly to bottom of calyx. In the calyx the septa are radially arranged except anteriorly, where a few septa on either side of the cardinal converge toward it. Externally in the apical portion of the corallum the arrangement is plainly tetrameral. The interseptal spaces are from three to four times as wide as a septum and flat at the bottom.

In transverse section the dissepimentarium is thickest in that part of the corallum above the base of the calyx. It is composed of numerous large cystose dissepiments, which may have their walls greatly and irregularly thickened with stereoplasm and which may form a large part of the calicinal wall. The dissepiments are elongated vertically and often extend laterally across several interseptal loculi. Some appear to inosculate and others interrupt the course of the septa toward the outer wall a short distance from it. On the axial side of the outer wall the septa, when interrupted, appear as low ridges. Near the axial ends of the minor septa deposition of stereoplasm may be so great as to form an inner wall beyond which the minor septa project but little internally. Sections below the base of the calyx have a distinctly biareal appearance. Peripherally the dissepimentarium shows numerous thick-walled dissepiments, normal and cystose, with heavy deposits of stereoplasm forming one or more rings. Septa rarely extend across it to the outer wall. Apical sections show that the dissepimentarium becomes narrower and less important. Tabularium is large and dominated by the major septa, which extend to the axis, often with considerable twisting and thickening. The edges of the tabulae appear between the septa in more or less continuous circlets.

The biareal nature of the interior is more distinct in longitudinal sections. The tabularium is very large, occupying nearly the whole of the region below the calyx, especially the apical part of the corallum. Tabulae are numerous, irregular, crowded in places, horizontal in the axial region, flat or gently concave, sharply dipping outward and downward peripherally. Dissepimentarium is largely confined to the region above the bottom of the calyx but may extend some distance below. Dissepiments are highly variable in size and shape, convex inwardly, with walls often greatly thickened by stereoplasm. Below the calyx there is generally only a series of single ones, but above there may be one, two or three overlapping sets. The outer wall is composed about equally of epitheca with its porelike structures and an inner deposit of stereoplasm which does not have them.

This species is the largest in the formation but is relatively rare, as only nine examples have been recovered. Its large size distinguishes it from the smaller species of the Independence and of the Lime Creek. From *Tabulophyllum expansum* Fenton and Fenton it differs in shape, in having fewer septa and a distinct fossula. From *Tabulophyllum magnum* Fenton and Fenton it differs in shape and in having more septa and a large fossula. From *Tabulophyllum ponderosum* Fenton and Fenton it varies in shape, in

having fewer septa, and in the presence of a fossula.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype, M. A. S. 937; paratypes, M. A. S. 938, 989.

TABULOPHYLLUM QUADRATUM Stainbrook, n. sp.

Plate 57, figures 7, 9, 15; plate 61, figure 6

Corallum simple, conical, expanding with moderate rapidity from the apex, gently curved, with cardinal side convex. Exterior somewhat rough because of several strong growth wrinkles. Epitheca thin, marked by septal grooves, those above the major septa being more prominent, and by epithecal pores. Measurements of the holotype and of a paratype are: height (calyx horizontal) 22.1 mm. and 54.5 mm. (calyx absent); length of cardinal side (calyx wall missing) 47.1 mm. and 54.5 mm.; length of counter side 22.6 mm. and 34.6 mm.; diameter of calyx 22.5 mm. and 27.4 mm.

Calyx circular, deep, with strongly sloping walls; bottom broad, slightly elevated centrally and depressed peripherally. A well-developed sulcus, occupied by the cardinal septum, extends from the axis to the calicinal wall and thence upward. Septa strong, numerous, in two sets alternating and numbering about 100. Major septa of posterior part extending to axis, those of anterior side reach the axis or converge strongly toward the cardinal septum, all twisted near axis and forming a sort of pseudocolumella. Minor septa short, confined to calicinal wall and region directly below. Tetrameral arrangement of the septa evident in calyx and in the axial portion of the corallum; main septa other than cardinal not distinguished from remainder.

Internally in transverse section the boundary between the tabularium and the dissepimentarium is not distinguished other than by the termination of the minor septa. Major septa slightly irregular and twisting; some of them may fail to reach the center. Inner dissepiments small, numerous, crowded, sometimes inosculating, the bars generally being concave axially. Outer dissepiments large, cystose, broad and interrupting the septa. In longitudinal section of an immature specimen the tabularium occupies the major portion of the corallum, only near the bottom of the calyx and above is a dissepimentarium distinguishable. Tabulae numerous, crowded, strongly and broadly convex at axis, generally bending downward peripherally. Dissepimentarium not apparent until corallum is 2 cm. high, increasing in breadth upward. Dissepiments generally small and confined to interseptal loculi in the inner part of the dissepimentarium but large and elongate in the outer, interrupting the radial continuity of the septa, and generally thickened by stereoplasm.

Mature individuals of *Tabulophyllum quadratum* when weathered have a quadrate outline with a corner at the site of each main septum. This condition is well shown in a large paratype which resembles in appearance some specimens of *Aulacophyllum* from the Cedar Valley beds.

Tabulophyllum quadratum is smaller than *Tabulophyllum dux*, is differently shaped either weathered or unweathered, has a less capacious calyx which proportionally occupies a smaller part of the corallum. It appears to be quite unlike any Lime Creek species and is distinguished from them readily by its quadrate shape.

Occurrence: Independence shale at Brandon, Iowa.

Types: Holotype, M. A. S. 941 A; paratypes, M. A. S. 941.

TABULOPHYLLUM CLINATUM Stainbrook, n. sp.

Plate 57, figures 1, 3, 10

Corallum simple, small to medium in size, conical, increasing slowly in diameter from the apex, slightly curving, with cardinal septum outermost. Exterior nearly smooth, broken by several shallow wrinkles of growth. Epitheca thin, marked by small interseptal ridges and narrow septal grooves. Measurements of holotype and of a paratype are: length of anterior side (incomplete) 28.2 mm. and 52.4 mm.; length of posterior side (incomplete) 12.6 mm. and 26.5 mm.; greatest diameter 16.1 mm. and 24.1 mm.

Calyx moderately deep, the bottom flat or slightly elevated centrally; wall steep, relatively thin, in anterior side is a well-developed fossula, which is deepest at the junction of calyx floor and wall. Septa abundant, thin, numbering about 120 in two sets. Ma-

jor septa extending to or nearly to the axis and twisting strongly, only a few actually reaching the axis. Minor septa short, generally confined to the calicinal wall, extending but a short way inward. Cardinal septum reduced, situated in the fossula, other main septa not distinguishable from the major septa. In apical portion of the corallum septal arrangement is tetrameral but is radial in calyx except on either side of the cardinal septum, toward which a few lateral septa converge.

A longitudinal section of a small paratype shows that the tabularium occupies nearly all of the interior of the corallum. Tabulae numerous, generally flat and horizontal axially but bending downward peripherally and extending nearly to outer wall. A large paratype with a broken calicinal wall shows numerous dissepiments developed after a certain nature size is attained. They do not occur inwardly beyond the ends of the minor septa.

The smaller size of the corallum, its distinct shape and the axial twisting of the septa in the calyx distinguish this species from other members of the genus in the Independence shale. The small size and shape separate it from Lime Creek forms.

Occurrence: Independence shale at Brandon, Iowa, Amana shale, Amana, Iowa.

Types: Holotype, M. A. S. 940 A.; paratypes, M. A. S. 940, 939, 574.

Genus MACGEEA Webster

Macgeea WEBSTER, 1889, Am. Naturalist, vol. 23, p. 710.—FENTON AND FENTON, 1924, Michigan Univ. Cont. Mus. Geology, vol. 1, p. 53.—LANG AND SMITH, 1935, Geol. Soc. London Quart. Jour., vol. 91, p. 552, text figs. 10, 11.—SMITH, 1945, Geol. Soc. America Special Papers no. 59, p. 27.

Although this genus has been discussed by several authors, its characters have not been completely described. The following summary has been obtained from a study of numerous examples of the genotype from the type locality and of other species from the Independence shale.

Corallum simple, conical, expanding rapidly in the lower portion, increasing but little after maturity, curved, generally with the cardinal side outermost, often irregular in growth and distorted at the apex by attachment. Typically small, seldom exceeding 2 cm. in diameter and 3 cm. in height. Exterior with numerous growth wrinkles and striae of increment; sometimes longitudinal wrinkles or depressions may cut across the interseptal ridges. Epitheca thin, smooth, showing septal edges beneath; often worn and partly absent. Below rim of calyx for a distance of 5 mm. or less the epitheca is absent because of nondeposition, and the outstanding edges of the septa form a conspicuous collar.

Calyx usually oval, often elongated along the cardinal-counter axis, broadest posteriorly and produced a little anteriorly, but may be circular or variously shaped because of irregular growth; deep, extending nearly to the apex in geologically earlier species and in immature examples of the genotype; outer wall thick, nearly vertical; floor variable, often flat or with a central depression, which has sloping walls and which may, unless floored by a tabula, extend nearly to apex. A distinct fossula occurs in the medial anterior portion.

Septa abundant, strong, numbering from 60–75, in two sets; major septa extending nearly to center or to cardinal septum in the calyx, to center in early species, or to axis in apical portion of corallum, generally twisting slightly near center, and projecting farther inward than the minor septa on the calyx wall and farther outward on the collar. In earlier species and less so in the genotype the cardinal septum, the alar septa and the two major septa immediately anterior, are larger than the other major septa and give the calyx in some forms a distinctly trifoliate appearance. The counter septum is distinctly small, scarcely larger than the minor septa on either side. Minor septa alternate with the major, are about half as thick at the calicinal rim; a short way below the rim they decrease rapidly in size and continue downward chiefly as linear series of spiculae or papillose projections. In well-preserved specimens the septa may be serrate, especially within the calyx, and all are finely trabeculate.

The septa above the upper edge of the epitheca are firmly united by dissepimental tissue to form a rigid wall of moderate thickness. Arrangement of the septa is tetrameral both on exterior and in the calyx. Nearly all the septa in the cardinal quadrants converge

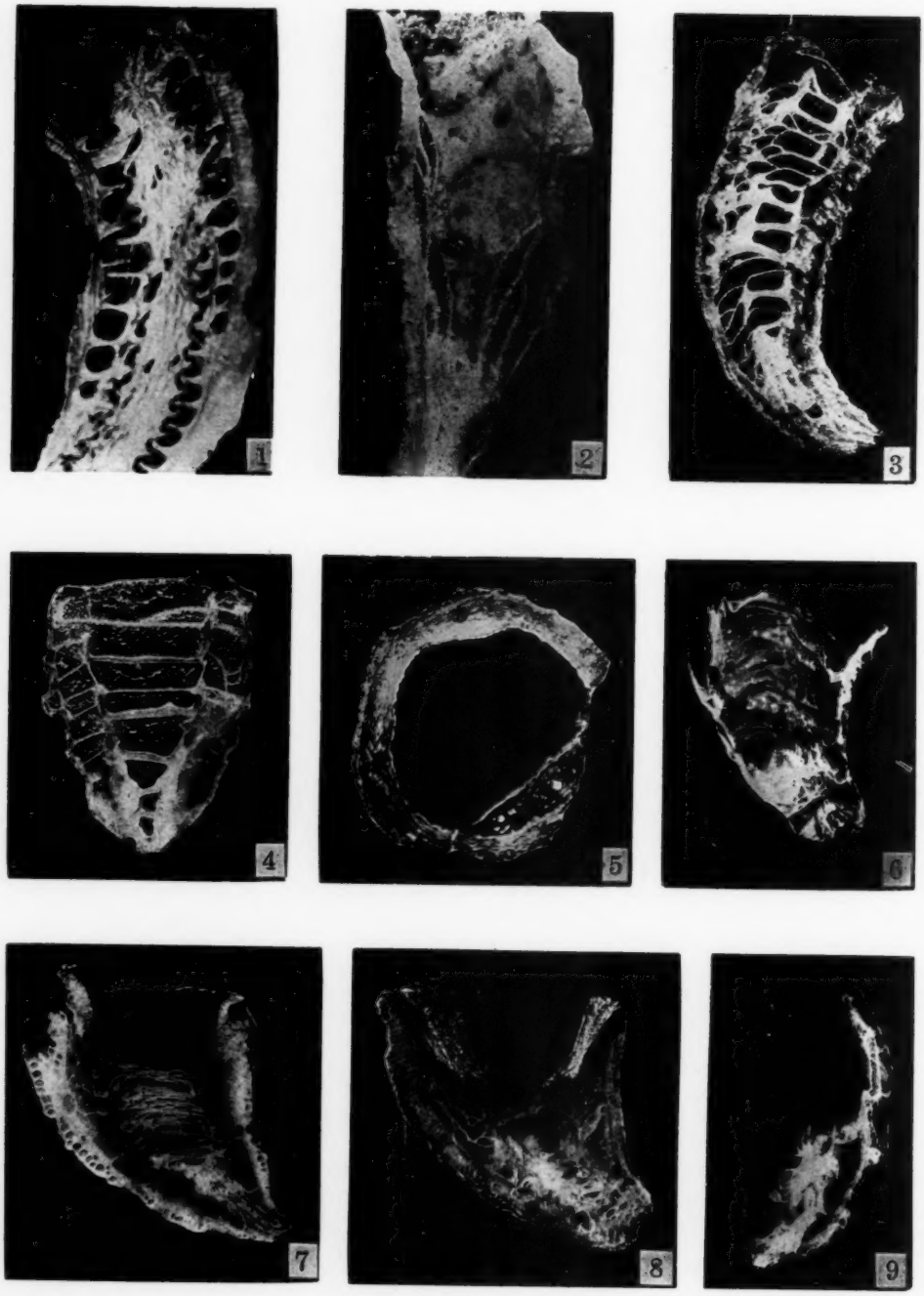
strongly toward the cardinal septum or into the fossula, where the former may be absent axially. The septa immediately posterior to the alar septa converge toward them. Lang and Smith (1935, text figure 10) give a diagrammatic transverse section of *Macgeea solitaria*, but it is somewhat misleading as they show the septa as strictly radial and farther from the center than is actually the case below the bottom of the calyx.

In transverse section the boundary between the tabularium and the dissepimentarium is not clearly distinguishable although the barlike structures near the inner wall are usually dissepiments. Septa under high magnification appear to have two lamellae of darker material with stereoplasm on each side and between. Axially beyond the inner wall these lamellae apparently are against each other but may separate slightly for short distances, especially at the septal terminations. Minor septa end abruptly just within the inner wall, while the majors extend nearly to the axis, where they twist slightly and may be rhopaloid. In the earlier portion of the corallum some of the major septa may reach the axis. All septa are greatly dilated at the inner wall and decrease in thickness axially and distally; generally the dilation of the major septa ends a short distance axially within the inner wall. The latter is a conspicuous feature and is a nearly solid deposit of stereoplasm except for the small openings made by the horseshoe dissepiments. Although close to the outer wall, it appears to be a true inner wall homologous to that in *Acervularia* and in some species of *Hexagonaria*. Carinae, however, are not present in *Macgeea*.

In longitudinal section the tabularium is large, occupying the major part of the corallum, but its boundary is not always definite. In the lower portion of the corallum and in the fossular area it is generally close to the thick inner wall but separated from it by inwardly convex dissepiments. Tabulae numerous, highly variable in extent, unequally spaced, often crowded, tending to be horizontal but slightly convex distally; they extend across the tabularium in most instances in others only halfway and may be overlapped by one from the other side. Peripherally the tabulae and dissepiments may overlap at the outer border of the tabularium. The dissepimentarium is divided into two regions by the development of the double inner wall, formed by the thickening of the septa, deposition of stereoplasm, and by the walls of a vertical median series of dissepiments. The latter are convex upward, similar in size and shape. They have been called "horseshoe dissepiments." They are set off from the dissepiments on either side by solid walls and are thus within the collar that forms the rim of the calyx. Between the inner wall and the epitheca is the peripheral series of dissepiments, which, in the genotype, are generally flat and horizontal but may be slightly concave or convex. In *Macgeea thomasi* Stainbrook they are usually outwardly and downwardly convex. The inner series of dissepiments is composed of axially, and to some extent upwardly, convex dissepiments, few in the apical portion but several ranges deep in the upper part. The epitheca is composed of several irregular sinuous dark laminae with lighter calcareous tissue between.

Besides the genotype, *Macgeea solitaria* Webster, in the Lime Creek beds, there are two species in the Independence shale, one in the Amana beds and several in the Shellrock limestone.

Lang and Smith (1935, p. 553) have suggested that *Macgeea* may have been derived from the plocoid coral genus *Phillipsastrea*. No evidence of this derivation is seen in the Iowa Devonian. In the first place *Macgeea* appears earlier in the Independence shale while *Phillipsastrea* does not appear until late in the Cedar Valley. Secondly all Iowa species are strictly simple and show no tendency to reversion to the compound form. *Macgeea* has tetramerally arranged septa, not radial. In order for *Phillipsastrea* to have given rise to *Macgeea*, the radial arrangement of the latter would have to change to the tetrameral while those of the distal parts are often radial. In addition to the assumption of the simple habit, a fossula would have to be developed. Smith and Lang mention carinae as usually present in *Phillipsastrea*, often strongly so; if this is true, carinae would have to disappear in the origination of *Macgeea*. The occurrence of hysterocorallites was not observed in Iowa species of *Macgeea*. They do occur in several species of tetra-



Stainbrook, Devonian Corals

corals in the Cedar Valley limestone, but here they appear to be phenomena developed in simple species rather than reversions to compound ancestors. Solitary individuals of *Phillipsastrea woodmani* (White) in the Cerro Gordo shale of the Lime Creek have the septa radially arranged and no collar. It may be that the relationship between *Phillipsastrea* and *Macgeea* is due to common descent rather than to one arising from the other.

MACGEEA PARVA Webster

Plate 57, figure 8; plate 58, figures 8, 9; plate 60, figures 6, 9

Macgeea parva WEBSTER, 1889, Am. Naturalist, vol. 23, p. 711.

Corallum small, conical, expanding rapidly at first from the apex, then maintaining same diameter through the mature stages; strongly curved apically, nearly straight after mature diameter is attained, the cardinal side convex; oval in cross section with the anterior-posterior diameter the larger. Exterior generally smooth except for a few strong, shallow, linear growth wrinkles, which are more numerous on the lateral portions of the corallum. Epitheca thin, complete except for a narrow band below the calicinal rim, shows septa and dissepiments beneath. Dimensions of two typical hypotypes are: height 17.1 mm. and 17.7 mm.; length of convex side 22 mm. and 22.7 mm.; greatest diameter 9.9 mm. and 9.3 mm.; least diameter 8.3 mm. and 8.1 mm. A small example from the discovery pit whence Webster obtained his type specimen is 10.1 mm. high, 12.1 mm. along cardinal side, 7.3 mm. in greatest diameter and 6.5 mm. in the least. The dimensions of this specimen are but slightly larger than the measurements of Webster's type.

Calyx circular to oval, being usually anteroposteriorly elongated, deep, but not as deep as broad; walls vertical or steeply sloping, the bottom broad and flat. Collar forming rim of calyx low, seldom more than 1 mm. high. Septa well developed, about 40 in number, in two sets. Major septa strong, extending to center of calyx, and twisting to form a pseudocolumella, which does not project into the calyx; they are considerably larger than the minor septa and alternate with them, are thicker at the inner wall but decrease rapidly in strength on either side. Minor septa short, confined to inner wall within the calyx but extending to the epitheca below the collar. Distal edges of the septa rounded and finely trabeculate. A slight, shallow cardinal fossula extends to outer wall. Septa tetramerally arranged in lower portion of corallum, nearly radial above.

Internally in transverse section the epitheca is thin and may be about one-fourth as thick as the inner wall. The septa are strongly dilated at this wall but decrease rapidly in thickness on either side. Major septa extend to axis, twist slightly, and may form a pseudocolumella. Minor septa extend slightly inward from the inner wall, but external to it they reach the epitheca and with the major septa form a series of chambers there. In longitudinal section the major

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EXPLANATION OF PLATE 61

FIGS. *1*—*Metriophyllum iowense* Stainbrook, n. sp. Longitudinal section, ×4, of a paratype, M. A. S. 921, Brandon Iowa. (p. 410)

2, 5—*Ceratopora auletica* Stainbrook, n. sp. *2*, Longitudinal section, ×6, of a paratype. *5*, Transverse section, ×8, of a paratype, Both M. A. S. 946, Brandon, Iowa. (p. 424)

3—*Syringaxon independense* Stainbrook, n. sp. Longitudinal section, ×4, of a paratype, M. A. S. 923, Brandon, Iowa. (p. 406)

4—*Syringaxon calvini* Stainbrook, n. sp. Longitudinal section, ×4 of a a paratype, M. A. S. 928, Independence, Iowa. (p. 408)

6—*Tabulophyllum quadratum* Stainbrook, n. sp. Longitudinal section ×1.5, of a paratype, M. A. S. 941, Brandon, Iowa. (p. 418)

7—*Zaphrentis praecedens* Stainbrook, n. sp. Longitudinal section, ×2, of a paratype, M. A. S. 935, Brandon, Iowa. (p. 413)

8—*Charactophyllum praecursor* Stainbrook, n. sp. Longitudinal section ×2, of a paratype, M. A. S. 954, Brandon, Iowa. (p. 415)

9—*Macgeea thomasi* Stainbrook, n. sp. Longitudinal section, ×2, of a paratype, M. A. S. 807, Brandon, Iowa. (p. 422)

part of the corallum is included in the tabularium, but the boundary between it and the dissepimentarium is not distinct; the border is near the inner wall in the early portion of the corallum but a little distant from it near the bottom of the calyx. Tabulae numerous, thin, somewhat irregular in extent and spacing, generally horizontal and flat, but may be a little convex or concave; some, especially in the fossular region, may slope axially. Dissepiments in three groups; a convex, axially inclined series within the inner wall, one, two or three deep; a single vertical series of horseshoe dissepiments in the inner wall; and a peripheral group, usually horizontal and convex or concave. Inner wall thin and in some specimens solidified by the deposition of stereoplasm.

Macgeea parva is readily distinguished from other members of the genus by its small size, method of growth, slightly oval calyx, and low septal collar.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype in C. L. Webster collection, present whereabouts unknown. Hypotypes, two in Calvin Collection, S. U. I. from discovery pit; M. A. S. 932, 933.

MACGEEA THOMASI Stainbrook, n. sp.
Plate 58, figures 1–7; plate 59, figure 14; plate 61, figure 9

Corallum simple, small, conical, rapidly expanding from apex, strongly curved, with the cardinal side outward, subquadrate in section, with alar sides flattened or even gently concave, broadest posteriorly. Exterior rugose, marked in mature examples by numerous strong growth wrinkles, which are widest anteriorly, and by somewhat irregular vertical linear depressions, which may or may not be parallel to the septal grooves. Immature individuals usually smoother, with faint or no evidence of septal grooves. Epitheca thin, showing septa and dissepiments beneath in many instances, extending distally within 4 or 5 mm. of the calycinal rim.

Calyx subquadrate in outline, extended along the anterior-posterior axis, broadest posteriorly, and with sides near alar septa flattened or concave so as to give it a trifoliate appearance; rim strong, formed by septa and inner wall making a conspicuous collar; deep, generally extending more than halfway to the apex; wall abruptly sloping from the rim at first, then less rapidly to the axis; bottom small, concave, and trifoliate. Septa stout, 60–72 in number, in two sets; major ones considerably the larger, thicker and more projecting, extending to or close to the center; minor septa similar, alternating with them, confined to inner wall within calyx, strongly lamellose external to the inner wall, firmly united with the major septa by stereoplasm, reaching the epitheca below the collar. In well-preserved examples the septa are finely trabeculate and appear to be serrate near the rim of the calyx. The trabeculae are small papillose ridges on the sides of the septa and are directed inward and downward within the calyx, downward on rim of calyx, and inward on the collar.

Septal arrangement strongly tetrameral within calyx and on exterior, the septa on either side of the cardinal septum curving toward it. Cardinal septum, alar septa, and the two major septa immediately anterior to the latter are noticeably larger than the others of the major cycle and project more strongly into the calyx. The counter septum is the same size as the adjacent minor septa. A cardinal fossula is variably developed.

Internally in transverse section the septa are strongly dilated at the inner wall but decrease rapidly in thickness away from it. Inner wall formed by septal dilation, addition of stereoplasm and walls of horseshoe dissepiments, minor septa scarcely projecting inward beyond the inner wall. Major septa are thin within the tabularium and twist a little toward the center. In longitudinal section the tabulae are numerous, irregular, usually flat or concave, and appear to be more abundant beneath the cardinal fossula. In the apical portion of the corallum the tabulae apparently extend to the inner wall but in the later part are separated from it by an axially arching inner series of dissepiments. Inner wall thin, apparently double because of the single series of small horseshoe dissepiments enclosed; these appear as small oblong upwardly vaulted cavites. Between the inner wall and epitheca is the peripheral series of dissepiments, flat, concave or outwardly convex, and occasionally overlapping.

Macgeea thomasi is readily distinguished

from *Macgeea parva* Webster, with which it occurs, by its larger size, rougher exterior, more broadly conical shape, trifoliate contour of the calyx, alar flattening and more numerous septa. From *Macgeea solitaria* (Hall and Whitfield) it is separated by its smaller size, more ovate and deeper calyx, more rugged exterior, unique trifoliate outline of the calyx, and enlargement of the cardinal and alar septa. In examples of these species of the same size, the septa of *Macgeea thomasi* are much sturdier.

Occurrence: Independence shale at Independence and Brandon, Iowa.

Types: Holotype in Calvin Collection, S. U. I., is from the coal prospect pit where the Independence fauna was first discovered; paratypes M. A. S. 807, 930, 931.

Order TABULATA Milne-Edwards and Haime
Family FAVOSITIDAE Milne-Edwards and Haime
Genus ALVEOLITES Lamarck

ALVEOLITES cf. A. ROCKFORDENSIS Hall and Whitfield

Plate 58, figure 46

Alveolites rockfordensis HALL AND WHITFIELD, 1873, New York State. Cab. Nat. History, Ann. Rept. 13, p. 229.

One example of *Alveolites* is almost completely attached basally to the shale substratum. Although incomplete, it measures about 7 cm. in greatest breadth and 5 cm. at right angles thereto. It is about 5 mm. thick in the central portion and decreases to a thin edge peripherally. The calices are small, much flattened, subrhomboidal in shape, and very oblique to the surface; about six may be counted in the space of 5 mm. Minute ridges in the calices of some corallites may represent septa. Because of poor preservation, sections are unsatisfactory and give little information regarding internal structures.

Although dissimilarities in some details from *Alveolites rockfordensis* are apparent, they may be due to differences in preservation. Until other and better specimens are secured, this coral may be tentatively included in that species.

Occurrence: Independence shale at Brandon, Iowa.

Type: Hypotype, M. A. S. 948.

Genus THAMNOPORA Steininger

THAMNOPORA ELLIOTTI Stainbrook, n. sp.

Plate 58, figure 43

The single example is apparently the distal part of a branch of a ramose corallum. It is not well preserved and most of the calices are filled with pyrite. Calices are circular, closely aggregated, and directed inward and downward. About six may be counted in the space of 5 mm. Walls are thick, about one-fourth as broad as an average calyx, apparently formed by alternating light and dark layers of calcareous material. Tabulae flat, complete, and moderately numerous. Mural pores large, circular, and apparently few. The specimen is 9.1 mm. in diameter.

Only one short piece of a corallum has been collected. Pyrite partially encrusts it and fills many calices. Enclosure in pyrite is a common condition in the fossils of the Independence shale.

It differs from *Cladopora floydensis* Fenton and Fenton in its larger size and in having more numerous corallites, 12 having been counted in the space of 10 mm. instead of seven as in the Lime Creek species; the forms may be congeneric.

The genus has recently been discussed at length by Dr. Stanley Smith (1945).

Occurrence: Independence shale at Independence, Iowa; collected by L. P. Elliott from the debris thrown out of the coal prospect pit.

Type: Holotype, Calvin Collection, S. U. I.

Family AULOPORIDAE Nicholson
Genus CERATOPORA Grabau

Ceratopora GRABAU, 1899, Boston Soc. Nat. History Proc., vol. 28, p. 414.

Ceratopora is a genus of auloporoid corals distinguished by its nonanastomizing suberect corallites, deep funnel-shaped calices with costae and spinose trabeculae, and coarse internal cysts. Generally the corallites are larger than those of *Aulopora* and the presence of cysts and trabeculae and the absence of transverse tabulae further separate the genera. It differs from *Cladochonus* in having a non reticulated wall structure. One species occurs in the Independence shale and several are known in the Cedar Valley limestone above.

CERATOPORA AULETICA Stainbrook, n. sp.
Plate 57, figures 2, 4, 6, 11–13; plate 59, figures 1, 6; plate 61, figures 2, 5

Corallum small, dendroid, erect, but generally represented in collections as simple corallites with one or two short branchlets. Corallites elongate, trumpet-shaped, proximally slender and circular in cross section, expanding gradually, curved, especially distally near aperture. Calices circular, with walls thin at the rims but thickening gradually proximally; deep, continuous with central cavity or closed by the growth of internal cysts. Well-preserved examples show vertical ridges, minutely papillated and resembling septa on the inner surfaces of the calices. Surfaces between these ridges bear minute porelike pits, which do not, however, come to the exterior. In some specimens the papillae are elongated and spinose resembling those described by Grabau.

Interior of the trumpet-shaped terminal corallites usually open or with a few cysts, but the trunklike corallites are generally filled so that the interiors are closed. Cysts are convex upward, elongate parallel to the axis, and distally imbricating. In some specimens the cysts are nearly transverse and resemble tabulae to a slight extent.

Increase in corallites may be single or dichotomous; when one corallite is given off, it is as a rule on the convex side of the mother corallite; when two are given off they are nearly on opposite sides of the mother corallite. Where it has been observed the cavity of the daughter corallite is continuous with that of the mother. Walls of the corallites thick, formed by alternate layers of light and dark material. The dark substance in longitudinal sections is composed of somewhat irregular laminae which join, disengage, and rejoin the adjacent laminae. There may be as many as 10 of the dark laminae, but the clear material forms a greater share of the wall. No reticulate structure between the dark laminae was observed. The walls of the cysts have the same structure but there are, at most, only two or three of the dark laminae. No spines or "trabeculae" were seen on the cysts.

Exterior marked by numerous transverse striae and a few strong growth wrinkles; the latter are especially prominent on the proximal portions of the corallum. The terminal corallites are generally smoother, with abundant striae. Apparently the external longitudinal ridges are absent in this species, but faint markings resembling them were seen in several examples.

A typical terminal corallite, the holotype, is 19.5 mm. long and 4.1 mm. in diameter. Another example, a paratype, and apparently a proximal corallite, is 20.1 mm. long and 4 mm. in diameter.

Ceratopora auletica is considerably smaller than *Ceratopora jacksoni* Grabau, commonly has the axial portions of the corallites completely closed, lacks the spinose processes on the cysts, and has the longitudinal external ridges very slightly developed if at all.

The distal corallites of this species greatly resemble in form, dimensions, and manner of growth the specimens of *Pyrgia michelini* illustrated by Milne-Edwards and Haime (1850). It was at first thought that these resemblances are more than coincidental and that perhaps the two species are generically related, but the presence of cysts and nonreticulate walls shows that *Ceratopora auletica* differs from *Cladochonus*, with which *Pyrgia* had been placed by Nicholson and Etheridge. Nicholson and Etheridge illustrate a form supposedly *Cladochonus* (*Aulopora*?) *michelini* Milne-Edwards and Haime but it apparently differs from their *Monilipora crassa*, which is true *Cladochonus* as stated by Girty (1925) and by Hill and Smyth (1938).

Occurrence: Independence shale at Independence and Brandon, Iowa. The holotype and several paratypes are from debris thrown out of the original discovery pit at Independence.

Types: Holotype, Calvin Collection S. U. I.; paratypes, Calvin Collection, M. A. S. 945–947.

PLEXITUBA Stainbrook, n. gen.

Corallum repent, small to medium-sized, corallites circular in cross section, increasing generally in size after budding or maintaining same diameter throughout; distal corallites, where not crowded, prostrate and attached to substratum by nearly their full lengths or, if crowded, forming an irregular plexus by growing around and over one another. In latter case attachment may take

place at intervals or tubules may form a mass with some tendency toward upward growth by mutual attachment and support. Increase is predominantly uniserial, but two tubules may diverge from one parent calyx. Calices circular, directed upward, generally at right angles to the elongate axis of the corallite, situated at termini of erect portions several millimeters in height; deep, gradually contracting downward because of the thickening of the outer wall and the formation of internal cysts. In some instances the interior of a corallite may be open, but generally, at places where tubules diverge, cysts close the internal cavity completely. Others in longitudinal section may be open axially from one junction to another with cysts along the sides. Inner sides of calicinal walls as far as observed without striae or vertical ridges; one specimen shows a few minute pittings. Walls of corallites thick, in transverse section highly magnified they are seen to consist of a series of fine concentric lamellae of dark material with lighter stereoplasm between. The lamellae are irregularly undulating, touching and retouching those on either side, or some may unite to form a coarser dark band. On one side of a corallum the clear material may be thicker and form the larger part of the wall, but this, too, may show many tenuous strands within. The dark lamellae, greatly magnified, are composed of numerous extremely tenuous strands, and their darker color appears to be due to the crowding of these minute structures. No indication of a reticulate structure similar to that of *Cladochonus* was seen. In longitudinal section the same structural details of the walls of the corallites are evident; they are similar to that in the walls of *Aulopora* and *Ceratopora*.

Within the interior the cystose structures occur especially in the proximal portions at the junctions of the corallites. They are more or less longitudinally elongate, convex inward, and may close the interior of the corallites completely. The wall of the cysts in thin sections highly magnified have the same structure as the outer wall. Five or six cysts are present in a broken section of a corallite. The genotype is *Plexituba contexta* Stainbrook, n. sp.

Plexituba resembles *Aulopora* in method of growth, especially in the repent form and in general appearance. It differs from that genus in the larger sizes of the corallites, in the lack of transverse tabulae, in the presence of cysts within the corallites, in the tendency toward upward growth by mutual support, in that the calices are not contracted but have the same diameter as the corallites, in that each calyx is situated at the end of an erect tube, which is at right angles to the remainder of the corallite, and in that as far as observed the corallites do not anastomose.

From *Cladochonus* (including *Monilipora*), *Plexituba* is distinguished by the nonreticulate structure of the outer wall of the corallites and by the possession of longitudinal internal cysts, which may close the interior completely.

Plexituba differs from *Ceratopora* in the smaller average size of the corallites, in the different method of growth and increase, in the lack of trabeculae within the calices, in the closing of the interior of the corallites by cysts, in the thickness of the outer wall of the corallites, and in the absence on the calicinal wall of longitudinal ridges which resemble septa. The structure of the outer wall is similar in both genera, but in this respect they are near *Aulopora*. *Ceratopora* is well represented in the Cedar Valley limestone, and these same differences are readily apparent in the species of the two genera.

From *Aulocaulis* Fenton and Fenton (1937), *Plexituba* is distinguished by the different method of growth of the corallum, by the different shape of the corallites, by the presence of well-developed internal cysts, by the absence of longitudinal ridges on the inside of the calicinal wall, and by the smaller size of the calices as compared to that of the corallites. *Ceratopora dichotoma* Grabau appears to belong to *Aulocaulis*.

The large size of the corallites and the presence of internal cysts distinguish the genus from *Auloporella* Grubbs (1939) and *Aulozoa* Grubbs (1939).

Plexituba is represented in the Independence shale only by the genotype, *P. contexta* Stainbrook, n. sp., but several undescribed species appear above in the Cedar Valley limestone. *Drymopora auloporoidea* Davis (1887) and also *Drymopora fructectosa* Davis (1887), (pl. 72, fig. 14–16) and possibly *Drymopora intermedia* Davis

(1887) may belong to this genus. *Ceratopora flabellata* Green may be placed in the genus also, as Dr. Grace Stewart (1938) mentions the smooth exterior, lack of internal spines, small size of the corallites, and apparent presence of cysts within. *Aulopora maxima* Fenton and Fenton (1937) also may be placed in *Plexituba* because of its auloporoid form, small size and cystose walls mentioned by the authors in transferring it to *Ceratopora*.

PLEXITUBA CONTEXTA Stainbrook, n. sp.
Plate 58, figures 44, 45; plate 59, figures 4, 9

Corallum variable in form, in some instances creeping, with corallites distant and attached to the substratum, in others with corallites crowded, attached to each other and more or less erect by mutual support but maintaining their individual identity. Corallites small, tubular, never coalescing, of nearly same diameter throughout or increasing slightly away from point of origin, not expanding near calyx; proximal portion larger, longer, recumbent, attached; distal part erect for several millimeters and turned abruptly at right angles from the remainder. Calices circular, at termini of short tubes, deep, decreasing in diameter downward, sometimes closed; walls thick, showing laminar accretion in cross section, irregularly and concentrically. Cysts elongate, inwardly convex and thin; in natural sections five or six may be seen variably arranged. Cysts may leave axial cavities in the corallites but at junctions they commonly close the tubes completely. Increase in the corallites is generally uniserial but may be biserial. Corallites average 2.2 mm. in diameter and 5.1 mm. in length from point of origin to calicinal geniculation; height of calicinal rim above remainder of corallite about 2 mm.

Repent portions of the corallum appear to be *Aulopora*, but the presence of cysts and absence of transverse tabulae are ready means of separation. The corallites are also longer and the walls thicker than those of members of *Aulopora*. *Plexituba maxima* (Fenton and Fenton) is similar to our form but attains larger dimensions—1.6 to 3 mm. in diameter of the corallites and 6.5 to 8 mm. in length. None of our examples of *Plexituba contexta* attains these maxima.

Occurrence: Independence shale at Brandon, Iowa.

Types: Holotype, M. A. S. 942 A; paratypes, M. A. S. 942, 943.

Genus AULOCAULIS Fenton and Fenton

Aulocaulis FENTON AND FENTON, 1937, Am. Midland Naturalist, vol. 18, no. 1, p. 119.

This auloporoid genus is distinguished from *Aulopora* by the larger size of its corallites, which generally maintain the same diameter for most of their length but which expand greatly at their distal ends. Also their calices are broader, circular, and surrounded by low upwardly directed rims. On their inner walls are faint vertical ridges unknown in *Aulopora*. Two specimens from the Independence shale may be placed here although neither shows more than one calyx.

AULOCAULIS SINGULARIS Stainbrook, n. sp.
Plate 57, figures 17–19

Corallum small, in specimens at hand consisting of a single calyx, from which diverge several tubules. Calyx is roughly circular, with low rim, which rises little above the tubules, directed upward, shallow, with broad flat bottom; no evidence of septa observed. Tubules long, broadly convex above, prostrate, attached for their full length below and generally closed distally. The holotype has three and the paratype four, diverging from a central calyx; two lie close together, but others diverge from them by wide angles. The holotype has a calyx 2.2 mm. in diameter, 1.1 mm. high, and its largest tubule is 3.8 mm. long and 1.6 mm. broad. The calyx of the paratype is 2.8 mm. in breadth, and one of its tubules is 5.8 mm. long.

Scarcity of examples has precluded sectioning, and the internal structures are unknown.

Aulocaulis singularis differs from *Aulocaulis expansum* Fenton and Fenton (1937) in its habit of growth, in having more numerous tubules branching from a calyx, in that the tubules are broader and flatter relatively. A similar form is present in the

Amana beds at Amana, Iowa, but it tends to occur in a linear series of calices with a single tubule between. Also its calices show obscure vertical internal ridges, which ally it more with *Aulocaulis annectans* (Clarke) from the Chemung of New York.

Occurrence: Independence shale at Brandon, Iowa.

Types: Holotype, M. A. S. 944 A; Paratype, M. A. S. 944.

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UPPER APTIAN NAUTILOIDS FROM COLOMBIA

J. WYATT DURHAM
California Institute of Technology, Pasadena, Calif.

ABSTRACT.—Three new species of nautiloids, *Cymatoceras colombiana*, *Eutrephoceras laverdei*, and *Heminautilus etheringtoni*, are described from the upper Aptian of Colombia. *Heminautilus etheringtoni* is discussed at some length and compared with *H. stantoni* (Scott) and *H. lallieranus* (d'Orbigny).

NAUTILOIDS are comparatively rare in the Cretaceous of South America. Insofar as the author is aware, none have previously been recorded from the well-developed and often highly fossiliferous marine Cretaceous of Colombia. The occurrence of three species in strata of upper Aptian age is therefore particularly worthy of note.

In the literature available, the following records have been found of nautiloids from the Cretaceous elsewhere in South America. None of the three species mentioned closely resemble the nautiloids here described.

Nautilus munieri Choffat is described and figured by Schlagintweit (1911, pp. 99–100, text fig. 3; pl. 6, fig. 9) from the Pampa de la Culebra, Peru, in beds which he considered as of Cenomanian age. From the figures and description, this species would appear to belong to a genus closely allied to *Heminautilus*, differing from *Heminautilus* largely in the absence of a flattened venter.

Nautilus perstriatus Steuer is described and figured by Weaver (1931, p. 392, pl. 43, fig. 297; pl. 44, figs. 304–305) from the province of Neuquen, Argentina, from strata ranging in age from upper Tithonian to Hauterivian. It appears to be a Cymatoceratid nautiloid, but unfortunately the suture is not figured or described.

Nautilus subplicatus Philippi is figured and discussed by Steinman (1895, pp. 65–68, pl. 4, figs. 1–3) from the Quiriquina formation of upper Senonian age, in Chile. According to the ornamentation shown on his figure 1, this species may possibly be referred to *Cymatoceras*. Steinman believed that all the other nautiloids recorded from this formation, *Nautilus d'orbignyanus* Forbes, *N. indicus* d'Orbigny, and *N. valenciennii* Huppé are referable to this same species.

I am deeply grateful to the Richmond Petroleum Company for supplying some of the specimens from locality A and the one specimen from locality C, while the Tropical Oil Company has kindly permitted the utilization of specimens and information from localities A and B. Dr. José Royo y Gomez of the Servicio Geológico Nacional of Colombia has supplied literature not available elsewhere, while Dr. A. K. Miller of Iowa State University has kindly criticized the manuscript.

DESCRIPTION OF LOCALITIES

Locality A.—Between El Valle and Payandé, Department of Tolima, Colombia. Along the side of the trail from Payandé to El Valle, about 100 meters north of the crossing of Quebrada Cobre (see fig. 1), at a point about 3.25 kilometers S 25° W from Payandé. Exposures of marly shale with abundant fossils on either side of trail, just before the trail drops down into quebrada. The fossils found here include gastropods, pelecypods, a few foraminifers, *Cheloniceras* sp., and a *Puzosia*-like ammonite in addition to the two new species of nautiloids, *Cymatoceras colombiana* Durham and

EXPLANATION OF PLATE 62

FIGS. *1–3, 5—Cymatoceras colombiana* Durham, n. sp. *1* (×1.1), *2* (×0.8), Holotype 35728; *2*, septal face at a radius of 45 mm. *3* (×1), *5* (×1.1), Paratype 35729; *3*, oblique view to show impression of external ribs on part of internal mold of last volution. (p. 429)

4—Heminautilus etheringtoni Durham, n. sp. Holotype 35731, ×0.7. View of venter showing shape of apex of hyponomic sinus. (p. 432)

Durham, Upper Aptian Nautiloids

Heminautilus etheringtoni Durham. On the basis of the presence of the genus *Cheloniceras*, it is believed that this outcrop is of upper Aptian age. This age is broadly corroborated by the finding of the ammonite *Douvilleiceras* about 2 kilometers downstream (higher stratigraphically), indicating a late lower or early middle Albian age for the strata at that point. This age is further corroborated by the general distribution of *Heminautilus* in strata of Aptian-Albian age (Scott, 1943, p. 90). Specimens of *Heminautilus* are moderately abundant at this locality, but only two individuals of *Cymatoceras* have been found.

Locality B.—Southeast of Becerril, along the east side of the Cesar Valley, Department of Magdalena, Colombia. The fossil locality is along the Rio Tocuy (see fig. 2), at a point about 18.5 kilometers N 67° E from La Jagua (Iberico), and about 13.5 kilometers S 52.5° E from Becerril. The Cretaceous sediments in this immediate area are carbonaceous black shales with calcareous concretions. Ammonites are fairly abundant in these concretions and occasionally occur in the shales. Fossils other than ammonites, except for occasional thin-shelled, small pelecypods, are scarce. The ammonite genera *Dufrenoya* and *Cheloniceras*, indicative of upper Aptian age, occur both above and below locality B, while various parahoplitid ammonites are quite abundant. Only one specimen of *Eutrephoceras laverdei* Durham, n. sp., was collected.

Locality C.—About 11 kilometers south of west from Coyaima, Department of Tolima, Colombia. The locality is in sandstones on the Quebrada Olini, distant about 2.35 kilometers in an airline, upstream, from the junction of the Quebrada Olini with the Rio Saldana. Locality generalized. Age probably upper Aptian. A single specimen of *Heminautilus etheringtoni* Durham, n. sp., was collected here.

DESCRIPTION OF FOSSILS

Genus CYMATOCERAS Hyatt

Cymatoceras HYATT, 1884, Boston Soc. Nat. History Proc., vol. 22, p. 301.

Genotype: *Nautilus pseudo-elegans* d'Orbigny.

CYMATOCERAS COLOMBIANA Durham, n. sp.

Plate 62, figures 1–3, 5; plate 64, figure 4; text figure 3G

This species is based on two specimens from locality A. One specimen, which is designated the holotype, is relatively complete, lacking only the body chamber, but is almost entirely decorticated. The other specimen consists largely of phragmocone,

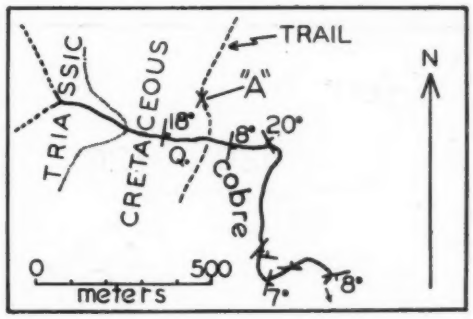

FIG. *1*—Detail at locality A.

but is about half eroded away laterally. Fortunately this second specimen retains the impression of part of the external ribbing on the body chamber and a small piece of the shell with the external surface showing a section of the ribbing (see pl. 62, fig. 3).

The conch is of moderate size, in both size and shape having considerable resemblance to *C. loeblichi* Miller and Harris (1945, pp. 6–7, pl. 2, figs. 1–4; pl. 3, figs. 3–4). At maturity the conch is slightly wider than high (see pl. 62, fig. 2), with the greatest width slightly ventral to the umbilical shoulder. In the holotype, which is completely decorticated in the umbilical area, the umbilicus is open and is slightly less than one-sixth the diameter of the conch. In the paratype the umbilicus still retains part of the original shell material. The umbilicus is open in this specimen and about one-eighth the diameter of the conch. In the holotype, the umbilical shoulder is evenly rounded, but the inner wall becomes vertical.

About midway of the last volution, the surface (decorticated, internal mold) of the paratype (pl. 62, fig. 3) bears the impression of the external ribs. The impressions show that at this diameter there were about three ribs to the centimeter. Fortunately a small piece of the external shell is also preserved in this area. This shows the external ribs to be about two and one-half times as wide as their interspaces. The internal impressions show that these ribs formed a broad ventral sinus more gently rounded than in

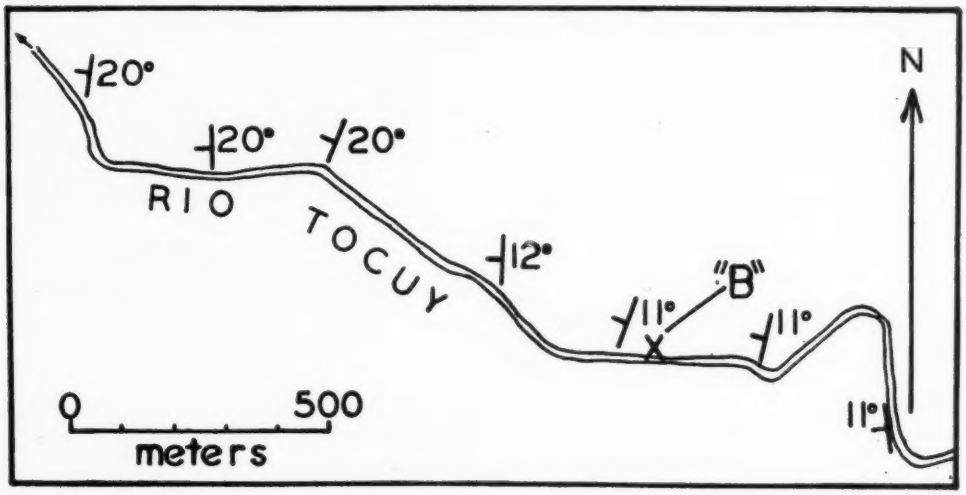

FIG. 2—Detail at locality B.

C. loeblichi, while the lateral sinuses are very shallow, being practically nonexistent.

The camerae are moderate in length. The sutures are rather sinuous (see fig. 3G), appearing to be about intermediate in character between those of *Cymatoceras* and *Paracymatoceras* Spath. The ventral saddle is broad and gently rounded, the lateral lobe is broad and moderately rounded, there is a fairly prominent saddle at the umbilical shoulder, and a deep, well-marked dorsal lobe with an even more conspicuous "annular lobe" within the dorsal lobe. This well-marked annular lobe is caused by (or causes) a marked posterior projection of the septal lobe with an even more "annular lobe" within the dorsal lobe. This well-marked annular lobe is caused by (or causes) a marked posterior projection of the septal face (see pl. 62, fig. 2). This projection is as wide as the annular lobe and continues ventrally for about one-third the distance to the siphuncle. The dorsal lobe and annular lobe are markedly deeper than those shown in *C. loeblichi* by Miller and Harris (1945, pl. 2, figs. 3, 4). At a diameter of 32 mm. the lateral lobes on the holotype are deeper than in the adult stage but are still evenly rounded. The siphuncle is small (about 3 mm. in diameter on a septal face about 30 mm. high) and dorsal of the center situated about two-thirds the distance from the venter to the dorsum.

Dimensions.—Holotype: maximum diameter 88 mm.; height of conch near last septum approximately 42 mm.; width of conch at same point about 50 mm. Paratype: maximum diameter 78 mm.

Remarks.—This species is referred to *Cymatoceras* instead of *Paracymatoceras* because the suture is not as sinuous as those shown by Miller and Harris (1945, pl. 4, figs. 1, 2; text fig. 3) for the genotype of *Paracymatoceras* and for *P. texanum* (Shumard). However if the dorsal and annular lobe of *C. loeblichi* are typical of *Cymatoceras*, then it is probable that the present species should be assigned to some other

genus, possibly *Paracymatoceras*. Of the North American species discussed and figured by Miller and Harris, the present species appears to be closest to *C. loeblichi* and *C.? neohispanicum* (Burckhardt). It is readily separated from *C. loeblichi* by the more sinuous sutures. Inasmuch as *C.? neohispanicum* is of about the same age as the present species it should be closely compared, but with no information available regarding the sutures and siphuncle of Burckhardt's species, it is believed best to keep them separate at present.

Occurrence.—Locality A, in association with *Heminautilus etheringtoni* Durham, n. sp. Age: upper Aptian.

Types.—Univ. Calif. Mus. Paleo. nos. 35728 (holotype) and 35729 (paratype).

Genus EUTREPHOCERAS Hyatt

Eutrephoceras HYATT, 1894, Am. Philos. Soc. Proc., vol. 32, no. 143, p. 555.

Genotype: *Nautilus dekayi* Morton.

EUTREPHOCERAS LAVERDEI Durham, n. sp.

Plate 63, figures 1, 2, 4; text figure 3H

This species is based on a single specimen from locality B. The specimen is complete except for the body chamber, and is well preserved but decorticated. The conch is moderately small, with a maximum diameter of about 56 mm., highly inflated, and well rounded. This species is more inflated than *E. dekayi* (Morton). At maturity the conch is wider than high (see pl. 63, fig. 4) with the greatest width at a point marked by a line tangent to the venter of the preceding whorl. Ratio of height to width of whorl 1:2. Umbilicus closed or practically so. Umbilical shoulder broadly rounded.

Suture (see text figure 3H) slightly sinuous: a broad very gently rounded ventral saddle; a very shallow lateral lobe; a gently rounded low lateral saddle at the point of greatest convexity; an umbilical lobe slightly more prominent than the preceding; a dorsal lateral saddle; and a distinct very broadly V-shaped dorsal lobe merging into an annular lobe. The dorsal lobe is the most conspicuous element of the suture; however, it does not produce any posterior folding of the septum as in *Cymatoceras colombiana* Durham, n. sp. Siphuncle midway between dorsum and venter, about 3 mm. in diameter at the last septal face. No traces of ornamentation on the decorticated exterior of the conch.

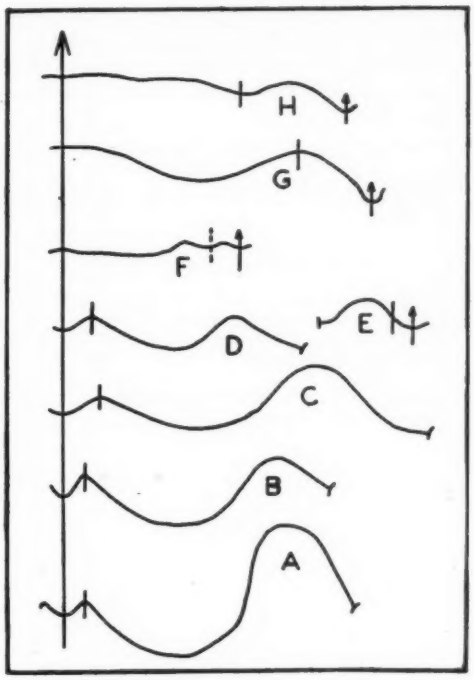

FIG. 3—Nautiloid sutures.
A, *Heminautilus lallierianus* (d'Orbigny). Modified and reversed after Scott (1943, text fig. 23, pl. 25, fig. 2) to agree with present orientation of sutures, ×½.
B, *Heminautilus stantoni* (Scott). Modified after Scott (1940, p. 1075) to agree with present orientation of sutures. ×½.
C–F, *Heminautilus etheringtoni* Durham, n. sp. *C*, At a radius of 85 mm. ×½; *D*, at a radius of 50 mm. ×½; *E*, dorsal part of suture at a radius of 70 mm., ×½; *F*, fourth suture, approximately ×2.
G, *Cymatoceras colombiana* Durham, n. sp. At a radius of 45 mm., ×½.
H, *Eutrephoceras laverdei* Durham, n. sp. Last suture, radius 35mm., ×½.

Dimensions.—Of holotype, greatest diameter 54 mm., height of conch at last septum 22.5 mm., width of conch at last septum 45.5 mm.

Remarks.—This species does not closely

resemble the description of any species available to me. The relative proportions of the height to the width of whorl (1:2) readily separate it from other described forms.

Occurrence.—Locality B, age upper Aptian.

Type.—Holotype, Univ. Calif. Mus. Paleo. no. 35730.

Genus HEMINAUTILUS Spath

Heminautilus SPATH, 1927, Paleontologia Indica, n. ser., vol. 9, mem. 2, p. 22.
Vorticoceras SCOTT, 1940, Texas Univ. Pub. 3945, pp. 1074–1075.

Genotype: Of *Heminautilus, Nautilus saxbii* Morris, 1848 (equals *Nautilus lallierianus* d'Orbigny, 1941); of *Vorticoceras, Vorticoceras stantoni* Scott.

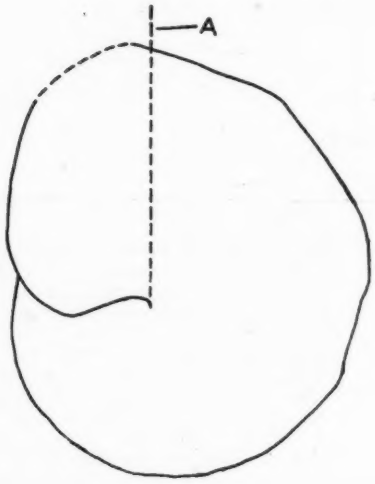

FIG. 4—*Heminautilus etheringtoni* Durham, n. sp. After holotype 35731, ×0.35, same specimen as pl. II, fig. 6. Outline of whorl and lappets. Restored in part after growth lines. *A*, line marking depth of hyponomic sinus.

HEMINAUTILUS ETHERINGTONI Durham, n. sp.

Plate 62, figure 4; plate 63, figures 3, 5–7; plate 64, figures 1–3; text figure 3C–F.

This species is based on a number of specimens from locality A where it is fairly common. The largest specimen, which still retains part of the exterior of the shell (pl. 63, fig. 6), is designated the holotype. All other specimens are more or less completely decorticated.

The conch is fairly large, with an inflated discoid shape. Whorls high, inflated, but with flattened venter and relatively straight flanks gently rounding into umbilicus. Umbilicus closed. At a radius of 50 mm., the venter is slightly concave on a medium-sized paratype (no. 35736), but on the holotype at the same radius the venter is slightly convex.

On the holotype, part of the external shell is preserved in various places. It shows that the ornamentation consists of growth lines and of low rounded ribs that are almost obsolete in some areas. On part of the body chamber, these ribs are quite prominent (pl. 63, fig. 6) and have a somewhat cymatoceratid aspect. In this area, there are three of these broad, low, rounded ribs to 18 mm. The ribs leave the umbilical area and curve sharply forward to follow the outline of the lappets, then curve strongly backwards towards the venter, and then cross the venter to meet in a broad V, thus forming a V-shaped hyponomic sinus (see pl. 62, fig. 4). These ribs are more prominent on the body chamber of the adult holotype than in earlier parts of the conch. The small paratype (no. 35733) shows fine ribs on the exterior of the first three camerae. On the holotype, the body chamber is about one-third of a volution in length. There is a fairly well marked lateral lappet (see pl. 63, fig. 6; and text fig. 4).

The suture (text figure 3C–F) appears to be typical of the genus, but with the elements less accentuated than in *H. lallierianus* or *H. stantoni*. The ventral lobe is shallower and the lateral saddle is less sharply rounded than in either of these species. On the small paratype (no. 35733) at a radius of 23 mm. the ventral lobe is nonexistent, with the suture crossing the venter in a straight line, while at a radius of 14 mm. there is a gently rounded ventral saddle. On the same specimen, the fourth suture (text figure 3F) shows a gentle ventral saddle, a broad very gentle lateral lobe, a sharp lateral saddle, a gentle umbilical lobe, a small lateral dorsal saddle and a well-marked small dorsal lobe. The mature

dorsal lobe is moderately deep, and the annular lobe is almost nonexistent.

The siphuncle is dorsal of the center of the whorl, being situated one-fifth of the distance from the dorsum. At a diameter of 21 mm., the siphuncle is nearly 3 mm. in diameter. The siphuncle is orthochoanitic, with very short funnels. The wall of the siphuncle is of different composition from the septa, appearing to contain considerable "impurities."

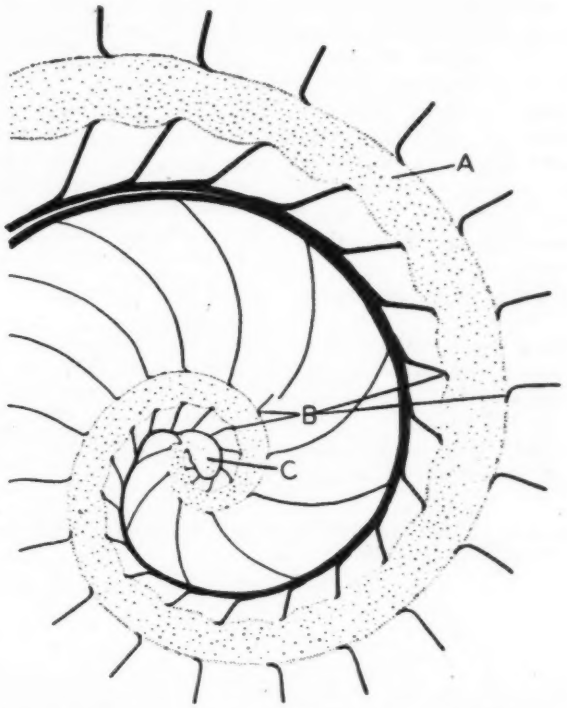

FIG. 5—*Heminautilus etheringtoni* Durham, n. sp. Paratype 35732, ×5, same specimen as pl. 64, figs. 1, 2. Median longitudinal section through first volution. Separation of venter and dorsum of second volution in last third of whorl caused by breakage. *A*, Siphuncle; *B*, funnel; *C*, umbilical perforation.

In median longitudinal section (text fig. 5, paratype no. 35732), the umbilical perforation can be seen, although the umbilicus is closed externally by the end of the first volution. In the single specimen sectioned, the siphuncle connects with the umbilical perforation through a constricted opening. This differs from the condition shown for *Nautilus* in Zittel's textbook (Hyatt, 1913, fig. 1123), but it may be possible that the tip of the conch was eroded before the completion of the first whorl although there is no discernible evidence of erosion. Another possibility is that the wall may have been broken through by recrystallization. The siphuncle appears to have passed through the first septum next to the dorsum, but by the second septum the siphuncle has migrated to a position about one-fifth the distance from the dorsum where it remains throughout the rest of the ontogeny of the conch. The funnels are short and enter into the wall of the siphuncle. The shell of the exterior of the conch is composed of at least two layers, particularly along the venter. The first nine chambers make up the first volution, and are proportionately larger than the succeeding ones.

At the fourth suture (paratype n. 35733), the conch (pl. 63, figs. 3, 5, 7) is subtrigonal in shape, generally resembling *Eutrepho-*

ceras laverdei. However the venter is slightly flattened and has a faint groove on it. The radius at this suture is about 4 mm. The growth lines show almost no hyponomic sinus at this diameter.

Dimensions.—Holotype: maximum diameter 153 mm., height of conch (at radius of 77 mm.) 53 mm., maximum width of conch at same point 59 mm.

Remarks.—This species differs from both *H. stantoni* and *H. lallierianus* in being more inflated than either. The suture closely resembles that of *H. stantoni* except for the shallower ventral lobe, but that species is much more discoidal. *H. lallierianus* approaches the present species in degree of inflation, but the sutural elements of d'Orbigny's species, as figured by Scott (1943), are much more strongly flexed than in this form (see text fig. 3).

Occurrence.—Localities A, C, age upper Aptian.

The specimen (paratype n. 35735) from locality C is badly weathered and eroded. It has a maximum radius of 110 mm., somewhat greater than the holotype.

Types.—Univ. Calif. Mus. Paleo. nos. 35731 (holotype); 35732–35736 (paratypes).

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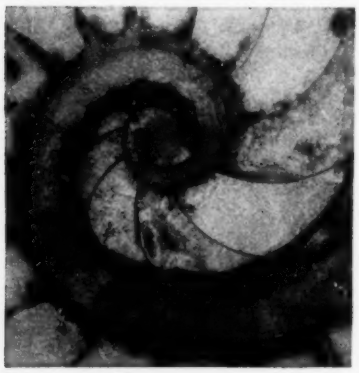
EXPLANATION OF PLATE 63

FIGS. *1, 2, 4—Eutrephoceras laverdei* Durham, n. sp. Holotype 35730, ×1.1. (p. 431)
3, 5–7—Heminautilus etheringtoni Durham, n. sp. *3, 5, 7*, Paratype 35733, ×5; note radial ribs on *3* and *5*. *6*, Holotype 35731, ×0.7. (p. 432)

EXPLANATION OF PLATE 64

FIGS. *1–3—Heminautilus etheringtoni* Durham, n. sp. *1* (×5), *2* (×2.5), Paratype 35732 showing siphuncle opening into umbilical perforation. *3*, Holotype 35731, ×0.8, broken section through umbilical area. (p. 432)
4—Cymatoceras colombiana Durham, n. sp. Holotype 35728, ×1.1. (p. 429)

Durham, Upper Aptian Nautiloids



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Durham, Upper Aptian Nautiloids

JOURNAL OF PALEONTOLOGY, VOL. 20, NO. 5, PP. 435–441, PLS. 65, 66, SEPTEMBER 1946

PLEMNOCRINUS, A NEW CRINOID GENUS FROM THE LOWER MISSISSIPPIAN

EDWIN KIRK
Geological Survey, Washington, 25 D. C.

A NEW GENUS, *Plemnocrinus*, is proposed for the reception of several new and old crinoid species from the Burlington limestone of the Mississippi Valley. So far as known, the genus is restricted to the Burlington. The described species have been referred variously to *Platycrinus*, *Pleurocrinus*, and *Eucladocrinus*. Excellent material showing the unusual arm structures characterizing the genus is now in hand. With the exception of one specimen, all of this material has been collected since the monographic treatment of the Camerata by Wachsmuth and Springer.

Genotype, *Plemnocrinus beebei* Kirk, n. sp.

GENERIC DIAGNOSIS

Crown: Explanate, rami extending outward like the spokes of a wheel, hence the generic name. The rami may extend horizontally or may incline a few degrees either below or above the horizontal.

Dorsal cup: Low, depressed basin-shaped to flattened. Plates varying from relatively thin to thick.

Tegmen: Varying from moderately low to highly arched. Anal opening excentric.

BB: Three, unequal, or fused to a pentagonal disk, which is usually concave and proportionally small compared with most platycrinoids.

RR: Large, widening gradually distad, then tending to constrict. In some species the median distal portions of the *RR* are greatly narrowed, and in one species the *R* is produced into a neck one-third the overall height of the radial.

IBr: One, axillary. Typically very long, heavy.

Arms: *IIBr* two in number, large. Typically the two series of *IIBr* in each ray are firmly united laterally. To the outside of the ray the *IIAx* bears two *IIBr*, the second axillary. In the resultant series of *IVBr* in one-half of the branch one more bifurcation may take place. The admedian face of *IIAx* supports two *IIIBr*. Depending on the species and age of the individual, there are a variable number of bifurcations above this. The rami are stout, incurved, and biserial. The resultant arm structure is superficially very like that of *Onychocrinus*. Ventral groove is closed by very heavy covering plates extending distad at least to the *IIBr* series.

Column: Although the cicatrix is small, the column is moderately stout. The columnals have the oval section and spiral twist characteristic of *Platycrinus*.

RELATIONSHIPS

The outstanding and distinctive structures of the genus are best shown in the species from the higher beds of the "Upper Burlington" limestone. The two species referred to the genus from the "Lower Burlington have structures logically antecedent to those of the typical forms. The inclusion of the two species is on the basis of reasonably inferred genetic affinity. Structurally they are more nearly like *Plemnocrinus* than any other generic group of the Platycrinidae.

In the Platycrinidae generally there is a prevailing trend toward diminution in size and number of the primibrachs. In later genera two primibrachs have been reduced to one. The single primibrach tends in general to become smaller, and may even be overlapped by the superjacent secundibrachs. The secundibrachs in the Platycrinidae as a whole are relatively small. In *Plemnocrinus* we have a notable reversal of this general trend. There is a great hypertrophy of both primibrachs and secundibrachs, forming a heavy horizontally di-

rected trunk. The short, heavy, incurved biserial rami of *Plemnocrinus* form a compact cluster, strikingly unlike that of *Eucladocrinus* and the Platycrinidae generally.

The typically low, flattened dorsal cup of *Plemnocrinus* and the distal constriction of the radials to form a rather sharply defined protruding neck seem to be characteristic of the genus. Three species, the arms of which are not known, have been referred to *Plemnocrinus* on the basis of these characteristics.

It will be noted that I have referred to *Plemnocrinus* all the species of the *discoideus* group of *Platycrinus* as defined by Wachsmuth and Springer except *Platycrinus discoideus* itself and *Platycrinus excavatus*. *P. discoideus* agrees fairly well with the "Lower Burlington" species referred to *Plemnocrinus* except for the small *IAx*. Considering its early stratigraphic position this feature could be overlooked. *P. excavatus* as identified by Wachsmuth and Springer could hardly be included, however.

CHARACTERISTIC SPECIES

PLEMNOCRINUS BEEBEI
Kirk, n. sp.
Plate 65, figures 2–5; plate 66, figures 7–9

There are five crowns representing this species in the Springer Collection. One has been freed from the matrix to expose the entire theca, and another has about 65 mm. of column preserved. Altogether the specimens show all the structural features reasonably to be expected.

P. beebei is the largest of the known species of the genus. The diameter of an average adult crown with the distal portions of the arms incurved is about 70 mm. In a specimen of this size the dorsal cup has a diameter of 28 mm. The largest specimen in hand is crushed, but an estimate of the normal diameter of the crown gives a measurement in excess of 80 mm. A theca with a diameter of 28 mm. has a height of approximately 20 mm., of which the dorsal cup constitutes slightly less than one-half.

The plates of the theca are very thick. The basals are fused into a symmetrical pentagonal unit. The center is somewhat excavate and in the older specimens well-defined rounded nodes form at the angles of the pentagon. The basals have a diameter somewhat greater than one-third the diameter of the dorsal cup. The radials are very heavy. They are beveled back from the margins. The rim of the central area thus formed tends to be somewhat raised above the general level of the plate, particularly along the proximal and distal margins. In older specimens these rounded ridges are very pronounced, outlining a horseshoe-shaped depressed area in the central portion of the plate. The tegmen is somewhat more than one-half the overall height of the theca and is moderately convex. It is made up of a relatively small number of heavy, tumid plates. The anal opening is excentric, nearly marginal. There is a low anal pyramid.

Normally the arms seem to have extended outward in a nearly horizontal plane. A small vertical movement seems to have been possible, as the arms may be found inclined slightly either upward or downward. The distal biserial armlets are usually found incurved, but they were apparently capable of free movement and in one specimen many of them lie in a horizontal attitude. The overall height of a set of arms does not exceed and usually is less than the diameter of the dorsal cup.

The primibrachs (primaxils) are massive. In the holotype the maximum size is 8 mm. in length by 8.5 mm. in breadth. In another specimen of about the same size a length of 9 mm. and a breadth of 10 mm. were measured. In primibrachs of this size a height of 8 mm. may be reached. The distal faces of the primaxil diverge at a very high angle and support two *IIBrr* on each face. The two series of *IIBrr* are firmly united laterally, and the two series combined have approximately the same breadth as the primaxil. The height of the combined secundibrachs is nearly equal to that of the primaxil.

It is difficult to describe accurately the distal portions of the arms, as the structures vary in detail with the age of the individual. More bifurcations appear in later stages of growth. One-half of one ray of the largest known specimen (pl. 66, figs. 8, 9) is almost completely preserved and well shown. $IIBr_2$ is axillary. The axillary face to the outside

of the ray descends abruptly, with the result that the lateral cluster of armlets lies at nearly right angles to the principal axis. In younger specimens the axillary faces are more symmetrical, and in consequence the angle of divergence of the lateral cluster is less. In this lateral branch there are normally two *IIIBrr*, the second of which is axillary. In the largest specimen there appear to be two supplementary plates, though there may be but one, and the apparent suture may be a fracture. In any event, the proximal plates of the branch abut against *IIAx*, $IIIBr_1$, and *IIIAx* of the main arm group. The first axillary of the branch bears an axillary brachial on its proximal face, which supports an undivided biserial ramus on one face and a bifurcating biserial ramus on the other. The distal face of the first axillary of the branch bears a stout biserial ramus that bifurcates. The admedian face of *IIAx* supports two *IIIBrr*, the second of which is axillary. The admedian face of *IIIAx* bears a biserial ramus that does not bifurcate, so far as preserved. The outer face of *IIIAx* supports two *IVBrr*, the second of which is axillary. The admedian face of *IVAx* bears a stout biserial ramus that apparently bifurcates. The outer face of *IVAx* bears a stout biserial ramus that bifurcates. Of the two resultant rami, the proximal ramus divides.

On the ventral surface, tegminal plates make contact with the proximal face of *IAx* on each side. These were doubtless covering plates, later incorporated in the tegmen. Distad *IAx* supports a pair of very large, heavy, high-curving plates on each side that interlock ventrad. Covering plates apparently extended distad at least as far as the series of *IIBr*, but the structures are hidden by the incurving biserial rami.

The column is oval in section with the characteristic spiral torsion of *Platycrinus*. It is relatively smaller and less flattened than is usual in *Platycrinus*.

Horizon and locality.—This species is found in the upper beds of the "Upper Burlington," generally known to the collectors of the past as Burlington-Keokuk Transition Beds, or Fish Bed. Probably through lack of knowledge of what was actually meant by these terms some recent authors have referred these beds to the Keokuk. As a matter of fact, much of the distinctive crinoid fauna of the "Upper Burlington" derived from these beds. Specimen, plate 66, figures 7–9, probably came from the quarry on Cascade Creek in the southern part of Burlington, Iowa. The other specimens probably came from the upper crinoid horizon in the quarry on Ninth and Angular Streets, Burlington, Iowa.

Types.—The holotype, S 4493, and paratypes, S 4494, 4495a, b, are in the Springer Collection, United States National Museum.

Remarks.—This species is dedicated to J. O. Beebe, who formerly lived near Burlington, Iowa. Without formal education and with limited financial resources, Beebe had unlimited enthusiasm for his avocation of collecting and preparing crinoids. His painstaking care in collecting from new localities discovered by him added greatly to our knowledge of the Burlington crinoid fauna. Most of the outstanding specimens of the genus here described were collected and prepared by him. Beebe's collection was purchased by Springer and is now incorporated in the Springer Collection of the United States National Museum.

The specimen of this species illustrated as *Eucladocrinus tuberosus* by Wachsmuth and Springer (1897, pl. 72, fig. 3) was at that time the only specimen of *Plemnocrinus* known with the arms preserved. The specimen is crushed laterally, giving the deceptive appearance of a highly arched dome, the only character one can imagine that induced them to refer it to *E. tuberosus*. There is in reality little resemblance between the two species. The relatively deep cup of *P. beebei*, with its strongly sculptured radials, and the constriction of the radials at the arm bases are quite unlike *P. tuberosus*. The resemblance of *P. beebei* to *P. homalus* is greater and is discussed under the latter species.

PLEMNOCRINUS BULLATUS Kirk, n. sp.
Plate 65, figure 1

This species is represented in the Springer Collection by a crown with a considerable portion of the arms preserved. There are also two thecas and one dorsal cup, representing

younger individuals.

The species is a moderately small one, the dorsal cup of the holotype measuring 22 mm. in diameter by 10 mm. in height. The other specimens are smaller, but the relative proportions of the cup are approximately the same. One uncrushed theca gives the following measurements: diameter, 15 mm.; height of cup, 6 mm.; and overall height of theca, 14 mm.

The dorsal cup is broadly conical. In the holotype the sides of the cup diverge at an angle of at least 110°. The actual measurement is larger, but allowance has been made for slight crushing. In the smaller specimens the angle averages about 100°. In basal view the outline is pentagonal, with nipplelike protrusions at the arm bases.

The sutures of the three basal elements are clearly shown. The combined basals form a symmetrical pentagon, which slightly exceeds one-half the diameter of the dorsal cup. The basals are protuberant and show clearly in lateral view. The radials are considerably wider than high. Distad the radial constricts, forming a median nipplelike projection. The articulating face of the radial is about two-fifths the width of the radial. The tegmen is high, domed, and at least in the younger specimens the interambulacral areas are sharply depressed. The anal opening is lateral in position and is but slightly above the level of the arm bases.

The ornamentation of the plates varies with the age of the individuals. In younger specimens the original five basals show as rounded elevations, with depressed areas between. In the older specimens these elevations are connected by broad ridges, forming a pentagon. Minor nodes may appear on the ridge, flanking the elevations at the angles. The margins of the radials in the younger individuals are beveled, with a raised median area, the perimeter of which parallels the outline of the radial. In the older specimens successive growth and resting stages are marked by a series of rounded parallel ridges, which in turn are parallel to the margins of the radial. In the holotype there are three such well-defined ridges. The ambulacral plates of the tegmen are tumid to subspinous.

The primaxil is large for a platycrinoid but does not have the extreme hypertrophy of the typical species of the genus. The first primibrachs are laterally apposed, and in both rays in which they are preserved one of them makes contact with the secundibrachs of the other half of the ray. The second secundibrachs do not make contact laterally. In all division series above the primaxil two brachials are involved. *IIAx* bears a moderately long stout biserial ramus to the outside of the ray. *IIIAx* bears a biserial ramus on its admedian face. *IVAx* bears a pair of biserial rami. No divisions have been seen in the biserial rami. Heavy covering plates are preserved in one ray, extending as far as the first bifurcation as seen.

Horizon and locality.—"Lower Burlington" limestone, Burlington, Iowa.

Type.—The holotype, S 4492, is in the Springer Collection, United States National Museum.

Remarks.—This species may readily be distinguished from any other species of the genus known by the low conical form of the dorsal cup and the prominent basals.

PLEMNOCRINUS CAVUS (Hall), n. comb.

Platycrinus cavus HALL, 1858, p. 527, pl. 8, figs 1a, b. "Burlington limestone, Burlington, Iowa." (Upper Burlington.)

Platycrinus cavus Hall. WACHSMUTH and SPRINGER, 1897, p. 715, pl. 67, figs. 8a, b.

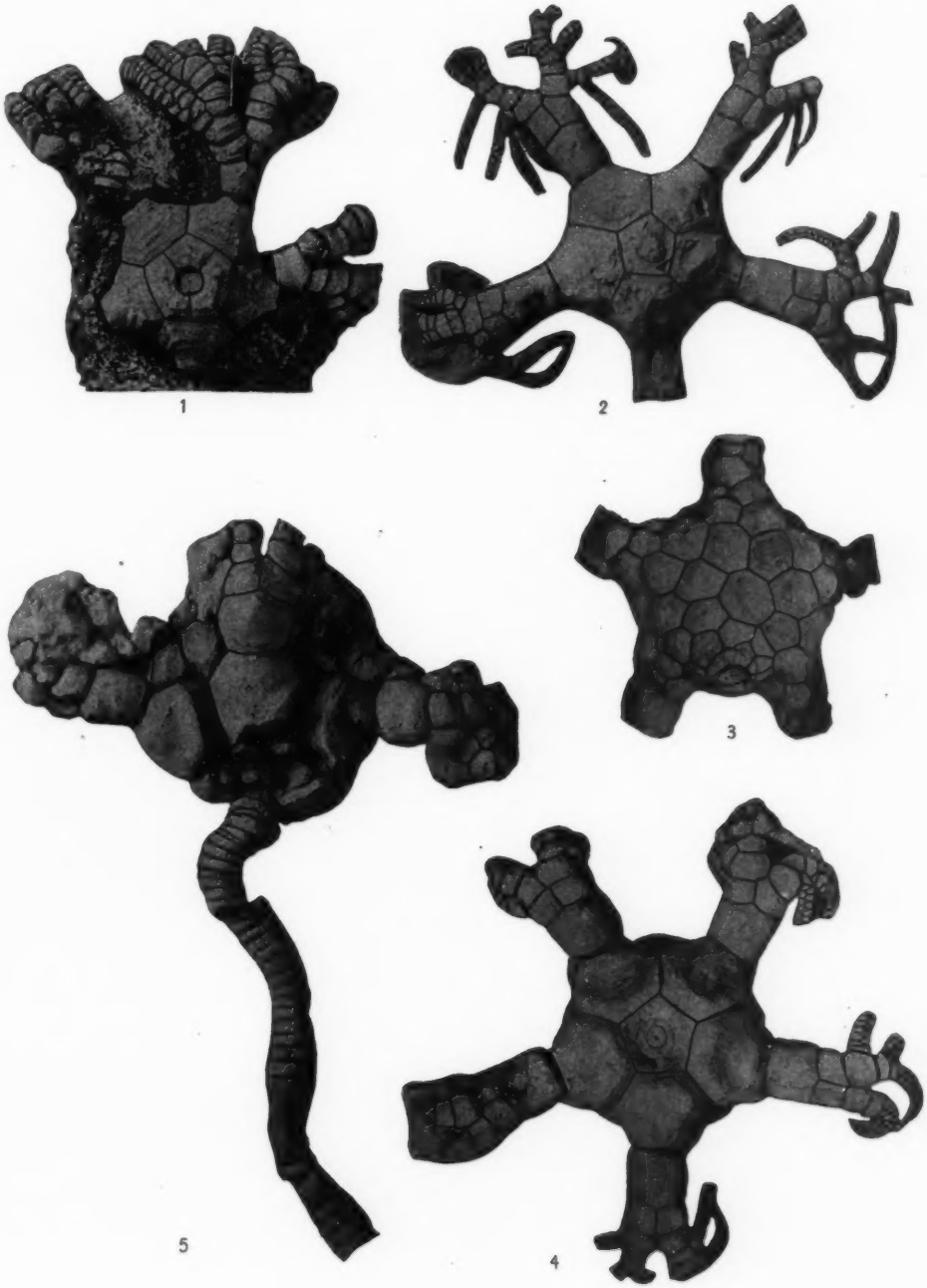
Platycrinus (*Pleurocrinus*) *cavus* Hall. WACHSMUTH and SPRINGER, 1881, p. 71.

This species is tentatively referred to *Plemnocrinus*. Without the arms definite identification is not possible. The dorsal cup is low and flattened. The radials are constricted distad, forming short protruding necks. In such characters as are shown the species best agrees with *Plemnocrinus*.

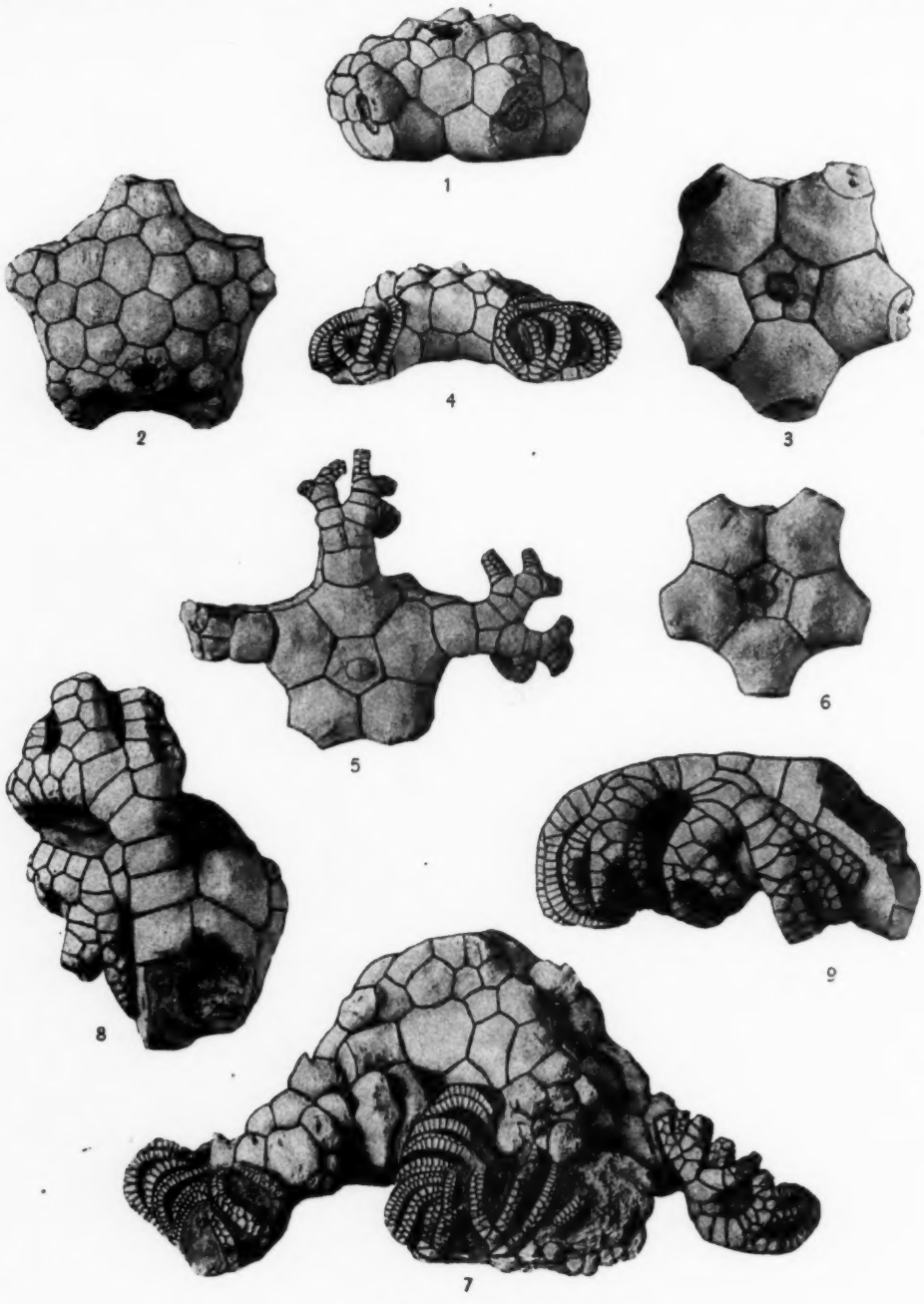
EXPLANATION OF PLATE 65

FIG. *1*—*Plemnocrinus bullatus* Kirk, n. sp. Basal view of holotype. (p. 437)

2–5—*Plemnocrinus beebei* Kirk, n. sp. *2*, Basal view of paratype. *3*, Tegminal, and *4*, basal views of holotype. *5*, Paratype. All figures natural size. (p. 436)



Kirk, *Plemnocrinus*



Kirk, *Plemnocrinus*

PLEMNOCRINUS GORBYI (S. A. Miller), n. comb.

Platycrinus gorbyi S. A. MILLER, 1891, p. 15, pl. 1, fig. 14. "Burlington limestone, Sedalia, Missouri." (Upper Burlington.)

This species is tentatively assigned to *Plemnocrinus* for the same reasons given in the case of *P. cavus*.

PLEMNOCRINUS HOMALUS Kirk, n. sp.
Plate 66, figures 1–6

This species is represented in the Springer Collection by eight thecas and one crown with the arms preserved in their entirety in two rays and partially preserved in another ray.

The plates of the theca are very thick. The largest theca has a diameter of 31 mm. and a height of 21 mm. The dorsal cup has a height of but 8 mm. The base of the cup is an essentially plane surface with a depressed median area. As viewed from below, younger specimens have a distinctly stellate outline. In older specimens the stellate outline is still retained, but the re-entrant angles are less pronounced. The tegmen is moderately elevated and somewhat flattened on top in older individuals.

The basals lie within the central depression. They are fused to three elements and in combination form a pentagon approximately one-third the diameter of the cup. In specimens of maximum size each of the original five basals is sharply tumid. The radials have a pronounced thickening along their lateral and proximal margins, though not so clearly defined as in *P. beebei*. In the median proximal portions of the plate this thickening may be accentuated to form fairly well defined rounded elevations. In a specimen of medium size the height of the radial is 0.8 the breadth. In a series of specimens of increasing size the height steadily decreases relative to the width, and in the largest specimen the height is 0.6 the width. The width of the facet in relation to the width of the radial in the same specimens shows the opposite trend, but not to an outstanding degree, ranging from 0.52 in the smallest to 0.54 in the largest.

The tegminal plates are large and tumid. The anal opening is excentric in position, and there is a low anal pyramid.

The arms have essentially the structure described in *P. beebei*, except that as seen there are fewer bifurcations. In one ray there are six terminal biserial rami and in the other, seven. This is a fairly young individual, and it might well be that in older specimens there would be more bifurcations. As preserved in the one individual, the arms slope downward. The ventral surface of the arms, at least as far as the first bifurcation, is closed by very large tumid covering plates.

Horizon and localities.—Higher beds of the "Upper Burlington" limestone, Lost Creek, some 8 miles southwest of Burlington, Iowa. All the specimens were collected by J. O. Beebe. A theca probably referable to the species is labeled as "Upper Burlington Limestone, Bear Creek Station, Marion Co., Missouri." This specimen was collected by R. R. Rowley.

Types.—The holotype, S 4496, and paratypes, S 4497a, b, are in the Springer Collection, United States National Museum.

Remarks.—*P. homalus* may be distinguished readily from *P. beebei* by its relatively lower dorsal cup with its flattened base. The species most nearly resembling *P. homalus* is *P. occidentalis*. Both have low dorsal cups with flattened bases and both have relatively low tegmens. The shapes and outlines of the radials in the two species are strikingly dissimilar in the older individuals and fairly distinctive even in young specimens, as will be noted in the measurements given of the radials of the two species. In *P. occidentalis* the height of the radial relative

EXPLANATION OF PLATE 66

FIGS. *1–6*—*Plemnocrinus homalus* Kirk, n. sp. *1*, Posterior; *2*, tegminal; and *3*, basal views of holotype. *4*, Lateral, and *5*, basal views of paratype. *6*, Basal view of paratype. (p. 439)

7–9—*Plemnocrinus beebei* Kirk, n. sp. *7*, Lateral view of specimen figured by Wachsmuth and Springer as *Eucladocrinus tuberosus*. *8*, Dorsal, and *9*, lateral views of an arm of this specimen. All figures natural size except *8* and *9*, which are ×1½. (p. 436)

to the width is consistently greater than in *P. homalus*. In *P. occidentalis* the relative height steadily increases with increasing size of the individuals, while in *P. homalus* the opposite is the case. Again the width of the facet relative to the width of the radial is consistently less in *P. occidentalis*, and while the relative width of the facet steadily decreases with increasing size of the individuals, the opposite is the case with *P. homalus*.

PLEMNOCRINUS OCCIDENTALIS (S. A. Miller), n. comb.

Platycrinus occidentalis S. A. MILLER, 1891, p. 10, pl. 1, figs. 5, 6. "Burlington group, Sedalia, Missouri." (Upper Burlington.)

Eucladocrinus tuberosus (Hall) (cited as synonym of). WACHSMUTH AND SPRINGER, 1897, p. 728.

The citation of this species as a synonym of *Plemnocrinus tuberosus* by Wachsmuth and Springer (1897, p. 728) is incorrect. The species is valid. It most nearly resembled *P. homalus*, n. sp., a comparison with which is to be found under the description of the latter species.

The species reaches a considerable size, one fragmentary specimen having an estimated diameter of 38 mm. Between 25 and 30 mm. in diameter seems to be average for mature specimens as found.

The dorsal cup is low, with flattened base. There is a slight median depression. The tegmen is unusually low for the genus but slightly exceeds in height that of the dorsal cup. The plates of the theca are much thinner than in any other known species of the genus. The most characteristic feature of the species is the form of the radial. The median constriction of the distal face of the radial is much more pronounced than in any other known species. In older specimens the projecting neck is sharply differentiated from the remainder of the plate and has a length of approximately one-third the overall height of the radial. In younger specimens the height of the radial is approximately three-fourths the height. In three medium to large specimens measured the height consistently held at 0.9 the breadth. The width of the arm facet in a young individual measured 0.47 the width of the radial. In a series of individuals of increasing size the width of the facet relative to the width of the radial steadily decreased until in the largest specimen it had a value of 0.4.

Horizon and localities.—Miller's type is described as from the "Burlington group, Sedalia, Missouri." Specimens are in hand from the upper beds of the "Upper Burlington" at Burlington, Iowa, and from equivalent beds at Hannibal, Missouri.

PLEMNOCRINUS SUBSPINOSUS (Hall), n. comb.

Platycrinus subspinosus HALL, 1858, p. 536, pl. 8, figs. 9, 10. "Burlington limestone, Burlington, Iowa."

Platycrinus subspinosus Hall. WACHSMUTH and SPRINGER, 1897, p. 717, pl. 66, figs. 9a, b.

Platycrinus (Pleurocrinus) subspinosus Hall. MEEK and WORTHEN, 1866, p. 173, pl. 15, fig. 6.

We may assume that the specimen figured by Meek and Worthen and Wachsmuth and Springer is referable to this species. As in *P. bullatus*, the overall structure agrees well with what we might expect in an early form of *Plemnocrinus*.

The relatively large brachials of the first and second series, the partial or complete lateral apposition of the secundibrachs, and the stout incurving biserial rami show approximately the same stage in development as *P. bullatus*. The flattened low dorsal cup and the elevated tegmen are characteristic.

PLEMNOCRINUS TUBEROSUS (Hall), n. comb.

Platycrinus tuberosus HALL, 1858, p. 534, pl. 8, figs. 7a, b. "Burlington limestone, Burlington, Iowa." ("Upper Burlington.")

Platycrinus tuberosus Hall. WACHSMUTH and SPRINGER, 1881, p. 76 (250).

Platycrinus (Pleurocrinus) tuberosus Hall. MEEK and WORTHEN, 1866, p. 172.

Eucladocrinus tuberosus (Hall). WACHSMUTH and SPRINGER, 1897, p. 728, pl. 72, figs. 4a–c. Not fig. 3 (=*P. beebei*).

Eucladocrinus tuberosus (Hall). BASSLER and MOODEY, 1943, p. 470.

Wachsmuth and Springer's reference of this species to *Eucladocrinus* seems primarily to have been made on the basis of the specimen with arms (1897, pl. 72, fig. 3). The specific identification of the specimen is in error. The specimen, here refigured, is assigned to *P. beebei*. Although the arm structure of the specimen was described, its

radically different structure from that of *Eucladocrinus* was not recognized.

P. tuberosus differs widely from all other known species of the genus. The dorsal cup is relatively very small and flattened. As pointed out by Wachsmuth and Springer, the arm facets are directed downward. The arm structure must, in consequence, have inclined downward to a marked degree. The tegmen is very high and domed.

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EARLY UPPER CAMBRIAN TRILOBITES FROM WESTERN GASPÉ

FRANCO RASETTI
Laval University, Quebec, Canada

ABSTRACT—Limestone conglomerates, probably of Canadian age, exposed in western Gaspé yield large Lower, Middle and Upper Cambrian faunas. The Upper Cambrian trilobites are described. Thirty-nine species, 26 of which are new, are discussed. Six new genera are established.

All the fossils discussed belong to one fauna, which is clearly of Dresbach age. Several of the diagnostic fossils of the *Cedaria* and *Crepicephalus* zones are represented, so that the stratigraphic position of the boulders yielding the fauna may be considered to correspond to the late *Cedaria* or early *Crepicephalus* zone. The boulders seem to represent an equivalent of the Murphy Creek formation of eastern Gaspé and of the Rockledge conglomerate of northwestern Vermont. Several genera of trilobites that were poorly known are illustrated by well-preserved material.

OCCURRENCE OF THE FOSSILS

Limestone conglomerates, associated with sandstone, quartzite, and shale, occur in the western portion of the north coast of the Gaspé peninsula in Quebec. The writer (Rasetti, 1945) has given a brief account of these exposures and of the faunas collected from the conglomerate boulders. The age of the conglomerates is not definitely established, but appears to be Canadian.

The limestone boulders in the conglomerates yield several rich trilobite faunas, in which Lower, Middle and Upper Cambrian fossils are represented. All these fossils occur in gray, fine-grained or sub-crystalline limestone. Boulders of very large dimensions occasionally occur, showing that they came from limestone beds of considerable thickness. No strata of similar lithology and age are known to occur in place in Quebec. The trilobite shields are fragmentary but otherwise very well preserved. The limestones of different ages are similar lithologically, so that the age of each species must be determined by its faunal associations.

The outcrops from which the collections were made occur in two areas, in the vicinity of Métis and in the vicinity of Grosses Roches, both in Matane county. The conglomerates are well exposed in the sea cliffs, but part of the material was collected from loose blocks of conglomerate. The fossils collected from each boulder were carefully kept separated. The study of the fossils showed that all those that could be identified as Upper Cambrian belong to one faunal assemblage, of undoubted Dresbach age.

In Table 1 all the species collected from each boulder are listed. This is important, in view of definitely establishing the age of those genera that are unknown elsewhere.

Almost all the fossils collected in the Upper Cambrian boulders are trilobites. A few brachiopods and one gastropod constitute the rest of the fauna.

Boulders designated by the letter M are from Métis, those designated by the letter G from Grosses Roches.

AGE OF THE FAUNA

The Upper Cambrian fauna here described includes a number of early Upper Cambrian genera that are well known from the Dresbach equivalents of the southern Appalachians, Missouri, and the Cordilleran province. In the list of diagnostic genera given by Lochman and Duncan (1944) for central Montana, three of the genera from Gaspé (*Brassicicephalus*, *Cedaria*, *Bynumia*) are given as characteristic of the *Cedaria* zone. One genus (*Blountina*) is considered characteristic of the *Crepicephalus* zone. Eight genera (*Blountia*, *Coosella*, *Holcacephalus*, *Kingstonia*, *Kormagnostus*, *Menomonia*, *Meteoraspis*, *Tricrepicephalus*) occur in both zones. Therefore it appears that the fauna from Gaspé corresponds either to the late *Cedaria* or to the early *Crepicephalus* zone.

An approximately equivalent fauna oc-

curs in place in the Murphy Creek formation in eastern Gaspé. The lithology of these strata, however, is quite different from that of the conglomerate boulders. Two or three species, in addition to a number of genera, are common to the two faunas.

A fauna that seems to be very similar to the one here discussed was described by Lochman (1938) from boulders in the Cow Head breccia of western Newfoundland.

Several of the genera here discussed are unknown in the typical Dresbach formation of North America but are present in the Rockledge conglomerate of northwestern Vermont (Raymond, 1937). This paper brings a contribution to the knowledge of these genera, some of which were not well understood on account of the poor preservation of the fossils in the Rockledge. Finally, six of the genera are new.

TABLE 1. FAUNAL ASSOCIATIONS IN THE UPPER CAMBRIAN BOULDERS

Boulder	M-1	M-7	M-16	M-17	G-3	G-18	G-28	G-29	G-30	G-40
Amquia truncata Rasetti, n. sp.						×		×		
Blountia cf. *B. mimula* Walcott						×				
Blountia gaspensis Rasetti, n. sp.							×			
Blountia nasuta Rasetti, n. sp.								×		×
Blountia sp.					×					
Blountiella immarginata Rasetti, n. sp.				×						
Blountina westoni Rasetti, n. sp.									×	
Brachyaspidion? spinosum Rasetti, n. sp.				×						
Brassicicephalus quebecensis Rasetti, n. sp.		×		×						
Bynumia metisensis Rasetti, n. sp.				×						
Cedaria gaspensis Rasetti, n. sp.								×	×	
Cephalocoelia impressa Rasetti, n. sp.						×		×		×
Cephalocoelia lata (Raymond)							×			
Cephalocoelia rotunda Rasetti, n. sp.		×	×	×						
Cephalocoelia? simplex (Raymond)						×				×
Coosella granulosa Rasetti, n. sp.							×			
Coosella sp.									×	
Cryptoderaspis metisensis Rasetti, n. sp.		×	×							
Hemirhodon emarginatus Rasetti, n. sp.							×			
Hemirhodon simplex Rasetti, n. sp.		×		×				×		
Holcacephalus cf. *tener* (Walcott)						×		×		
Homodictya imitatrix Raymond					×			×	×	
Kingstonia gaspensis Rasetti, n. sp.						×	×	×		
Kingstonia quebecensis Rasetti, n. sp.	×							×		×
Kingstonia walcotti Resser							×			
Kormagnostus simplex Resser				×		×	×		×	
Lecanopleura? punctata Rasetti, n. sp.							×			
Lecanopleura? tuberculata Rasetti, n. sp.				×						
Leiocoryphe? prisca Rasetti, n. sp.				×						
Madarocephalus minor Rasetti, n. sp.	×									
Matania ovata Rasetti, n. sp.						×				
Menomonia semele (Walcott)							×			
Meteoraspis borealis Lochman					×			×		×
Metisaspis hispida Rasetti, n. sp.		×		×						
Olenoides? trispinosus Rasetti, n. sp.				×						
Onchonotopsis pergibba Rasetti, n. sp.		×	×	×						
Shickshockia cristata Rasetti, n. sp.									×	
Tricrepicephalus sp. 1								×		×
Tricrepicephalus sp. 2					×					
Undetermined pygidium									×	

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to Dr. G. Arthur Cooper for supplying casts of types in the U. S. National Museum and to Dr. Christina Lochman for material from Missouri and central Montana that was very useful for comparison. He is also indebted to Mr. Hubert Lechevalier who helped him to collect the fossils in 1944. The field expenses in 1945 were defrayed by a Project Grant from the Penrose Bequest of The Geological Society of America.

SYSTEMATIC DESCRIPTIONS

Owing to the lack of any satisfactory classification for Upper Cambrian trilobites, the genera will be arranged alphabetically. An exception is made for the Agnostids, which, whether they are considered as trilobites or not, undoubtedly form a sharply separated group.

Only those forms that are well enough represented for a reasonably safe specific identification are described. The writer believes that no service is rendered to paleontology by naming every fragment in a collection, thus overburdening the zoological nomenclature with names of doubtful status. Particular care in this respect should be taken when dealing with species of prolific genera, or when a species is to be used as the type of a new genus.

AGNOSTIA

Genus KORMAGNOSTUS Resser, 1938
KORMAGNOSTUS SIMPLEX Resser
Plate 69, figures 32–34

Kormagnostus simplex Resser, 1938, Geol. Soc. Am. Special Papers 15, p. 49, pl. 9, figs. 11–13.

Specimens of a *Kormagnostus* that occur in several boulders are referred to Resser's species, as no significant differences could be discovered. Since Resser gave hardly any specific description, the specimens from Gaspé will be described in detail.

Cephalon with considerable relief. Posterior glabellar lobe slightly tapered, well defined at the sides by the dorsal furrows and in front by a straight transverse furrow. The anterior glabellar lobe is just suggested by a slight swelling of the shield, but there is no trace of a furrow to define it. There is a low elongated tubercle in the middle of the posterior glabellar lobe. This lobe bears an extremely faint pair of glabellar furrows at the sides. Occipital lobes well defined, triangular. The furrow that separates the occipital lobes from the glabella is regularly semicircular and bears a pair of deeper impressions. The pleural lobes fall rather steeply to the wide, shallow intramarginal furrow, which sets off a depressed marginal rim.

Pygidium with a convex, somewhat pear-shaped rhachis reaching the posterior furrow. There is a low tubercle in advance of

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EXPLANATION OF PLATE 67

The test is preserved in all the figured specimens unless otherwise indicated.

FIGS. *1–3—Amquia truncata* Rasetti, n. gen., n. sp., ×8. *1, 3*, Top and side views of cephalon; Laval U. 1002a, holotype. *2*, Cranidium; Laval U. 1002b, paratype. (p. 445)

4–6—Blountia cf. *B. mimula* Walcott, ×4. *4, 5*, Top and side views of cranidium. *6*, Pygidium; Laval U. 1003a–b. (p. 446)

7–10—Blountia gaspensis Rasetti, n. sp., ×2. *7, 8*, Top and side views of cranidium; Laval U. 1004a, holotype. *9*, Pygidium. *10*, Partly exfoliated pygidium; Laval U. 1004b–c, paratypes. (p. 446)

11–14—Blountia nasuta Rasetti, n. sp., ×3. *11, 12*, Top and side views of partly exfoliated cranidium; Laval U. 1005a, holotype. *13, 14*, Pygidia; Laval U. 1005b–c, paratypes. (p. 446)

15, 16—Blountina westoni Rasetti, n. sp., ×2. Top and side views of cranidium; Laval U. 1007a, holotype. (p. 447)

17, 18—Blountiella? immarginata Rasetti, n. sp., ×4. Top and side views of cranidium; Laval U. 1006, holotype. (p. 447)

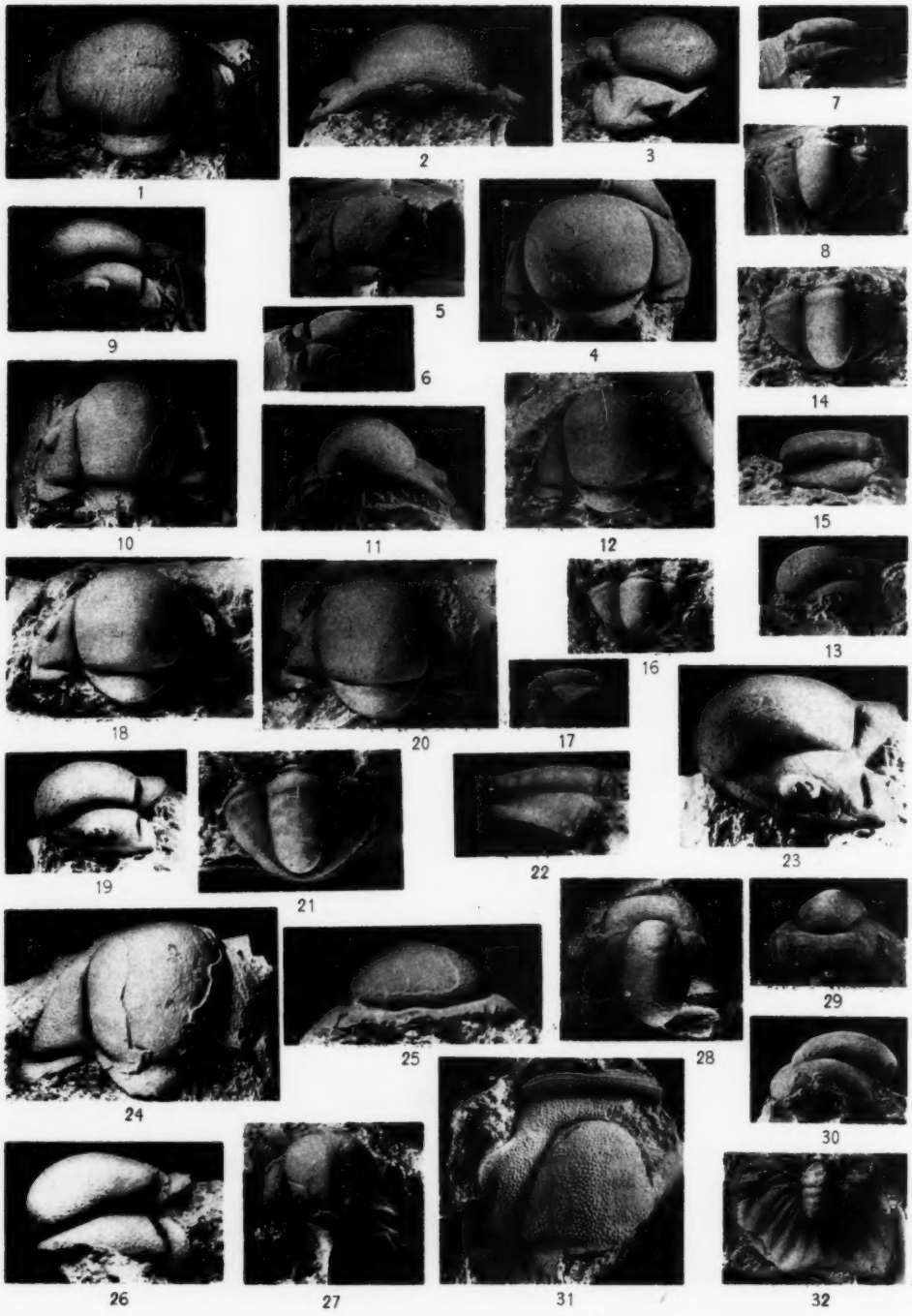
19, 20—Brassicicephalus quebecensis Rasetti, n. sp., ×6. Side and top views of cranidium; Laval U. 1009a, holotype. (p. 448)

21, 22—Brachyaspidion? spinosum Rasetti, n. sp., ×4. Top and side views of partly exfoliated cranidium; Laval U. 1008a, holotype. (p. 447)

23–25—Bynumia metisensis Rasetti, n. sp., ×3. *23*, Cranidium; Laval U. 1010b, paratype. *24, 25*, Top and side views of cranidium; Laval U. 1010a, holotype. (p. 448)

26–29—Cedaria gaspensis Rasetti, n. sp., ×2. *26, 27*, Top and side views of cranidium; Laval U. 1011a, holotype. *28, 29*, pygidia; Laval U. 1011b–c, paratypes. (p. 449)

Rasetti, Upper Cambrian Trilobites



Rasetti, Upper Cambrian Trilobites

the midpoint of the rhachis. Axial furrows indistinct. Pleural lobes narrow, subtriangular. Intramarginal furrow wide and shallow; rim wide, hardly elevated. Spines small but sharp. Surface of shields finely granulated.

This species seems to differ from the closely related *K. esterius* Lochman in possessing a narrower pygidial rhachis and a wider intramarginal furrow on the cephalon.

Boulders M-17, Métis and G-18, Grosses Roches.

Figured specimens: Laval University nos. 1001 a–c.

TRILOBITA (*sensu stricto*)

Genus AMQUIA Rasetti, n. gen.

Small trilobites known from the cephalon. Cephalon short and wide, not very convex as a whole although its separate parts possess considerable relief. Glabella ovate, slightly tapered, unfurrowed. Occipital furrow well impressed, occipital ring narrow and simple. Fixed cheeks and brim convex, rising somewhat above the level of the dorsal furrow. Palpebral lobes small, slightly elevated, distant from the glabella somewhat less than the glabellar width, situated considerably in advance of the glabellar midpoint. Ocular ridges faint, transverse. Rim all around the cephalon convex, well set off by an intramarginal furrow. The anterior outline of the rim, instead of being regularly semicircular as in most Cambrian trilobites, is straight or even slightly concave, giving the head a peculiar truncate aspect. This shape of the rim is obtained through its widening at the sides, since the intramarginal furrow is regularly curved. The preglabellar area is convex and wider than the rim.

Anterior branch of the facial suture directed forward and slightly outward, reaching the margin outside of the straight mesial portion. Posterior branch directed almost transversely, then curving backward and closely following the lateral margin of the head; extending for some distance on the upper surface of the genal spine. Hence the cranidium possesses small genal spines, which are enclosed in the larger genal spines belonging to the free cheeks. If only cranidia had been known, this trilobite would undoubtedly have been considered as proparian.

Genotype: *Amquia truncata* Rasetti, n. sp.

Remarks.—This peculiar trilobite does not seem to be closely related to any described. Separated cranidia somewhat resemble *Holcacephalus*, excepting the more rounded glabella and the truncated rim. However, *Holcacephalus* is truly proparian.

The name is taken from Amqui, a locality in the Matapedia Valley.

AMQUIA TRUNCATA Rasetti, n. sp

Plate 67, figures 1–3

The generic description supplies most of the available information on this species. The surface of the head is covered with a few, irregular, low ridges forming a reticulate pattern; this ornamentation, however,

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EXPLANATION OF PLATE 68

The test is preserved in all the figured specimens unless otherwise indicated.

FIGS. *1–8—Cephalocoelia impressa* Rasetti, n. sp., ×4. *1–3*, Top, front and side views of cephalon; Laval U. 1014a, holotype. *4*, Another cephalon. *5*, *6*, Top and side views of cranidium. *7*, *8*, Side and top views of pygidium; Laval U. 1014b–d, paratypes. (p. 450)

9–17—Cephalocoelia lata (Raymond), ×4. *9–11*, Side, top and front views of cephalon. *12*, Cranidium. *13*, Side view of another cranidium. *14–17*, Top and side views of two pygidia; Laval U. 1012a–e, plesiotypes. (p. 450)

18–23—Cephalocoelia rotunda Rasetti, n. sp. *18*, *19*, Top and side views of cephalon, ×4; Laval U. 1013a, holotype. *20*, Cranidium, ×4; Laval U. 1013b, paratype. *21*, *22*, Top and side views of pygidium, ×4; Laval U. 1013c, paratype. *23*, Side view of holotype cephalon, ×6, showing course of posterior branch of facial suture. (p. 450)

24–27—Cephalocoelia? simplex (Raymond), ×5. *24–26*, Top, front and side views of partly exfoliated cranidium. *27*, Exfoliated cranidium preserving the occipital spine; Laval U. 1015a–b, plesiotypes. (p. 450)

28–30—Cryptoderaspis metisensis Rasetti, n. gen., n. sp., ×3. Top, front and side views of cranidium; Laval U. 1018a, holotype. (p. 451)

31—Coosella granulosa Rasetti, n. sp. ×3. Cranidium; Laval U. 1016a, holotype. (p. 451)

32—Coosella sp. undet., ×2. Pygidium; Laval U. 1017a. (p. 451)

is so faint as to be visible only under proper lighting.

The holotype cephalon is 2.2 mm. long and 5.5 mm. wide.

Boulder G-29, Grosses Roches.

Holotype and paratypes: Laval University nos. 1002 a–e.

Genus BLOUNTIA Walcott, 1916
BLOUNTIA cf. B. MIMULA Walcott
Plate 67, figures 4–6

Blountia mimula WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 5, p. 399, pl. 61, figs. 4, 4a–c.

Blountia mimula Walcott. RESSER, 1938, Geol. Soc. America Special Papers 15, p. 63, pl. 12, figs. 18–19.

A small species of *Blountia*, represented by both cranidia and pygidia, is tentatively referred to the type species of the genus, since no distinctive characters could be discovered. However, in such a prolific genus as *Blountia* it is difficult to be certain of specific identity, especially since the type of the species is an immature and not too well preserved individual.

Boulder G-18, Grosses Roches.

Figured specimens: Laval University nos. 1003 a–b.

BLOUNTIA GASPENSIS Rasetti, n. sp.
Plate 67, figures 7–10

Known from several cranidia and associated pygidia.

Cranidium typical of the genus. Glabella almost straight-sided, moderately tapered, widely rounded in front. Occipital furrow indistinct on the outer surface, faintly impressed on the interior cast. Occipital ring very narrow. Dorsal furrows narrow and shallow. Fixed cheeks convex, continuing the slope of the glabella. Palpebral lobes small, situated on a line through the anterior third of the glabella. Anterior facial sutures rather strongly divergent. Posterior branch moderately curved, defining rather sharply pointed, backward-directed posterolateral limbs. Intramarginal furrow on posterolateral limbs indistinct on outer surface, impressed at least proximally on inner. Preglabellar area sloping rather steeply; rim as wide as preglabellar area, slightly convex, horizontal, defined by a change in slope rather than by a well-impressed furrow.

Pygidium subtriangular, widely rounded posteriorly. Axis occupying less than one-fourth of the width at the base, slightly tapered, rising little above the level of the pleural lobes. Axial furrows obsolete on outer surface; on inner surface, about 11 distinct segments. Axis reaching the rim, whose width is about one-fifth of the pygidial length. Pleural lobes moderately convex, unfurrowed. Rim of almost even width, flat, lying entirely below the level of the pleural lobes.

Outer surface smooth; interior cast punctate.

Length of largest cranidium 9 mm., width between tips of posterolateral limbs 14 mm. Length of largest pygidium 8 mm., width 12 mm.

This species is much like the genotype, *B. mimula* Walcott, differing chiefly in the larger size, less upturned cephalic rim, and pygidium with more numerous axial segments and more depressed rim. The same differences separate it from *B. janei* Lochman. *B. elongata* Resser may be close to the present species but is too poorly represented for specific identification. *B. terranovica* Resser has a very similar pygidium, but as the cranidium is unknown it is impossible to make a significant comparison.

Boulder G-28, Grosses Roches.

Holotype and paratypes: Laval University nos. 1004 a–f.

BLOUNTIA NASUTA Rasetti, n. sp.
Plate 67, figures 11–14

Known from several cranidia and pygidia, associated in two different boulders.

Glabella typical of the genus, defined by a shallow dorsal furrow. Fixed cheeks and palpebral lobes also of the usual size and shape. Anterior facial sutures slightly divergent in front of the eyes. Brim wide, almost entirely concave, with only a trace of an anterior furrow. Rim greatly widened mesially, forming a nasute extension. The rim has a low, vertical striated face.

Pygidium triangular, rather sharply pointed. Axis occupying somewhat more than two-thirds of the length, unfurrowed on the outer surface but showing eight or nine distinct segments on the interior cast. Axis low; pleural lobes depressed-convex, lower than the axis, unfurrowed even on the

cast of the inner surface. Rim poorly defined, widened mesially, extended into a postaxial termination that matches the pointed extension of the cephalic rim. Sides of pygidium with a narrow, vertical, striated face as the cranidium. Surface of test smooth. Length of largest cranidium 6 mm.; length of largest pygidium 7 mm., width 8 mm.

The only described species whose cranidium compares with the present one in the extension of the rim is *B. alexas* Walcott, in which, however, the anterior furrow appears to be well defined. The pygidium, although typical of *Blountia* in its general shape, differs from most of the others in being sharply triangular and relatively long and narrow, and is chiefly characterized by the postaxial extension of the rim.

Boulder G-29, Grosses Roches.

Holotype and paratypes: Laval University nos. 1005 a–g.

Genus BLOUNTIELLA Resser, 1938
BLOUNTIELLA? IMMARGINATA Rasetti, n. sp.
Plate 67, figures 17, 18

Cranidium moderately convex. Glabella of average convexity, parallel-sided, well rounded in front, unfurrowed. Occipital furrow very shallow, delimiting a narrow occipital ring. Dorsal furrows faintly impressed at the sides, somewhat deeper in front of the glabella. Palpebral lobes small, distant from the glabella somewhat less than half the glabellar width; situated in advance of the glabellar midpoint. Ocular ridges faint. Fixed cheeks and brim moderately convex. Anterior facial sutures slightly convergent. Brim without an anterior furrow, downfolded to form a vertical face. Posterior branch of the facial suture describing a regular curve convex toward the outside. Posterolateral limbs falcate, pointed, with a suggestion of an intramarginal furrow. Surface of test smooth.

Length of holotype cranidium 3.5 mm., width between the tips of the posterolateral limbs 6 mm.

This species is not typical of the genus, but the writer has been unable to find any described genus where it would fit better than in *Blountiella*. The chief difference from typical *Blountiella* is the lack of a rim. However, the form of the facial sutures is strongly suggestive of *Blountia* and related genera.

Boulder M-17, Métis.

Holotype: Laval University no. 1006.

Genus BLOUNTINA Lochman, 1944
BLOUNTINA WESTONI Rasetti, n. sp.
Plate 67, figures 15, 16

Known from the cranidium alone. Glabella tapered, rounded in front, defined by an exceedingly shallow furrow on the outer surface of the test. There is just a suggestion of the occipital furrow, defining a narrow occipital ring. Fixed cheeks and brim convex, continuing the slope of the glabella. Palpebral lobes short and narrow, distant from the glabella about one-third of the glabellar width; situated considerably in advance of the glabellar midpoint. There is a faint indication of an ocular ridge. Rim fairly wide, slightly convex, depressed, equaling in width the preglabellar area. Anterior facial sutures directed straight forward in front of the eyes, curving inward and crossing the rim obliquely. Posterior branch directed outward and backward, slightly curved, defining large, subtriangular posterolateral limbs that bear an indistinct intramarginal furrow.

Surface of test smooth. Length of holotype cranidium 8 mm., width between the tips of the posterolateral limbs 11 mm.

The cranidium of this species closely resembles those of the western species described by Lochman, especially *B. triangularis*, from which it differs in possessing a wider preglabellar area and a proportionately longer and narrower glabella. Unfortunately the pygidium of the present species has not been identified.

Boulder G-30, Grosses Roches.

Holotype and paratype: Laval University nos. 1007 a–b.

Genus BRACHYASPIDION Miller, 1936
BRACHYASPIDION? SPINOSUM Rasetti, n. sp.
Plate 67, figures 21, 22

A peculiar *Agraulos*-like cranidium is tentatively assigned to this genus, described from the late Middle Cambrian of the Cordilleran province.

Cranidium subtrapezoidal, rounded in

front. Glabella straight-sided, slightly tapered, truncated in front, unfurrowed. Dorsal furrows almost entirely obsolete on the outer surface, faintly impressed on the cast of the interior. Occipital furrow shallow. Occipital segment extended into a slender, relatively long, slightly upturned occipital spine. Palpebral lobes very narrow and inconspicuous, distant from the glabella somewhat more than half the glabellar width; situated almost opposite the anterior end of the glabella. Ocular ridges very faint, transverse, originating at the anterior angles of the glabella. Fixed cheeks and brim convex, presenting little change in slope with respect to the glabella. Facial sutures almost straight for most of their course. Posterolateral limbs with a wide, shallow furrow. Surface of test smooth.

Length of holotype cranidium (exclusive of the spine) 5.5. mm., width 7.5 mm.

In general aspect this cranidium is much like *B. rhynchinum* (Miller); the chief differences are the presence of an occipital spine, the lesser swelling of the brim (although the lighting accentuates this feature in Miller's photograph of the type) and the more quadrate glabella. Another Middle Cambrian trilobite that somewhat resembles the present species is *Agrauloides socialis* (Billings) from southeastern Newfoundland. It is difficult to establish the true affinities of this trilobite until more of it becomes known. It certainly cannot be placed in any described Upper Cambrian genus.

Boulder M-17, Métis.

Holotype and paratype: Laval University nos. 1008 a–b.

Genus BRASSICICEPHALUS Lochman, 1940

BRASSICICEPHALUS QUEBECENSIS Rasetti, n. sp.

Plate 67, figures 19, 20

Cranidium strongly convex. Glabella parallel-sided, well rounded in front, furrowless. Occipital furrow deep; occipital ring somewhat elevated, expanded mesially. Dorsal furrows narrow and deep. Palpebral lobes narrow, distant from the glabella half of the glabella width; situated considerably in advance of the glabellar midpoint. Ocular ridges narrow and faint. Fixed cheeks and brim convex. Brim well visible from above; anterior furrow marked at the sides, but entirely obsolete mesially. Posterolateral limbs wide, of average length, well rounded at the end; with a wide, deep intramarginal furrow that turns somewhat forward at the extremity. Surface of test smooth.

Length of holotype cranidium 3.5 mm., width between the tips of the posterolateral limbs 4.8 mm.

This species differs from *B. pulchellus* Lochman and *B. wolfensis* Lochman in the less tumid glabella and wider rim. It resembles more closely *B. snoyensis* Lochman, from which it differs in the proportionately longer and narrower glabella, narrower fixed cheeks, and more anterior position of the eyes.

Boulder M-17, Métis.

Holotype and paratype: Laval University nos. 1009 a–b.

Genus BYNUMIA Walcott, 1924

BYNUMIA METISENSIS Rasetti, n. sp.

Plate 67, figures 23–25

Known from the cranidium alone. Cranidium rather strongly convex in both directions. Longitudinal convexity strong in the posterior half, much weaker in the anterior half. Glabella faintly outlined on the upper surface, slightly tapered, rounded in front; occupying two-thirds of the cranidial length. Occipital furrow entirely obsolete. Palpebral lobes small, distant from the glabella less than one-third the glabellar width. Facial sutures directed straight forward in front of the eyes, then curving inward and meeting to form a rather obtuse point mesially. Posterior branch back of the eye directed outward and backward, then curving more definitely backward and reaching the posterior margin at a right angle. Thus the sutures form an angle at the palpebral lobes, and the cranidium is not so definitely triangular as in most species of *Bynumia*. Surface of test smooth.

Length of largest cranidium 8 mm., width between the tips of the posterolateral limbs 8.5 mm.

This species can definitely be assigned to the genus, although it differs from the genotype and from most of the other species in the less triangular shape of the cranidium. Only two species from the Rocky Mountains of Canada, described by Resser and doubtfully assigned to the genus, do not

have a triangular cranidium, but these can be distinguished by lacking the pointed outline of the brim.

Boulder M-17, Métis.

Holotype and paratypes: Laval University nos. 1010 a–f.

Genus CEDARIA Walcott, 1924

CEDARIA GASPENSIS Rasetti, n. sp.

Plate 67, figures 26–29

Cranidium moderately convex. Glabella tapered, rounded in front, unfurrowed. Occipital furrow shallow, occipital ring rather narrow. Palpebral lobes of medium size, distant from the glabella about one-fourth the glabellar width. Facial sutures in front of the eyes widely divergent, straight to the anterior margin. Width of brim about one-half the glabellar length. Rim narrow, flat, set off by a shallow anterior furrow that bears a series of shallow puncta. Posterior branch of facial suture directed transversely; posterolateral limbs of even width, rounded at the ends by the backward turn of the facial suture near the genal angle.

Pygidium two and one-fourth times as wide as long. Axis conical, furrowed for its entire length, showing eight or nine segments. Pleural lobes weakly convex, with seven or eight well-marked furrows that reach the narrow, slightly concave rim. A few shallow interpleural grooves are visible at the distal end of the segments.

Length of largest cranidium 7.5 mm., width between the tips of the posterolateral limbs 12 mm. The largest pygidium is 5 by 11 mm.

This species is either identical with, or at least extremely similar to a form occurring in the Murphy Creek formation of eastern Gaspé, where it is represented by fine complete individuals. The specimens from Murphy Creek show seven thoracic segments.

Among described species, the genotype, *C. prolifica* Walcott, closely resembles the present one. There seems to be little difference in the cranidia, but the pygidium of *C. gaspensis* is more transverse and has more segments. The number of thoracic segments is the same.

Boulder G-30, Grosses-Roches.

Holotype and paratypes: Laval University nos. 1011 a–g.

Genus CEPHALOCOELIA Raymond, 1937

Raymond erected a genus and a family for a supposedly proparian trilobite, *Cephalocoelia ovoides*, known from one incomplete cranidium. Examination of a good cast of the holotype has convinced the writer that the only posterolateral limb preserved in the specimen is accidentally broken and does not show the true course of the posterior branch of the facial suture. Moreover, examination of the type material shows that *Cephalocoelia ovoides* is undoubtedly congeneric with *Ucebia lata*. The latter species was described from better-preserved material, and Raymond did not consider it a proparian trilobite.

Neither species can be left in *Ucebia*, first, because the genus is invalid, being a synonym of *Kingstonia*, secondly, because the trilobites in question possess a strongly prominent glabella and other features that exclude any close relationship with *Kingstonia*. Hence *Cephalocoelia* is a valid genus and includes the described species *C. ovoides* and *C. lata*. *Ucebia simplex* Raymond may also be tentatively placed in the genus, although its characters bring it close to *Madarocephalus* and *Distazeris*.

The conglomerates in Gaspé yield several species of *Cephalocoelia*, which is one of the most common trilobites in the fauna. Besides two forms that are identified with *C. lata* and *C. simplex*, two new species are here described. They are represented by excellent material, so that a better diagnosis of the genus becomes possible.

Small trilobites with cephalon and pygidium of subequal size. Glabella strongly prominent, hemispherical or slightly expanded toward the front, unfurrowed. Occipital furrow deep and straight. Occipital segment rather wide, without spine in typical forms. Brim absent. Fixed cheeks greatly reduced in front of the eyes by the convergence of the facial sutures. Posterolateral limbs fairly wide, rather short, rounded at the end. Eyes small, opposite the glabellar midpoint; ocular ridges indistinct. Free cheeks narrow, faintly rimmed. Posterior branch of facial suture reaching the margin exactly at the genal angle; genal spines absent. Anteriorly, the facial sutures after crossing the margin of tbe cephalon diverge again from each other on the doublure, thus

separating a rostrum, which is set off from the cranidium by a marginal suture.

Pygidium subtriangular, rounded posteriorly. Axis strongly prominent, almost reaching the posterior margin, rounded at the end. Pleural lobes slightly convex; possessing a poorly defined, vertical, striated rim. Axis and pleural lobes show only traces of segmentation.

CEPHALOCOELIA LATA (Raymond)
Plate 68, figures 9–17

Ucebia lata RAYMOND, 1937, Geol. Soc. America Bull., vol. 48, p. 1103, pl. 2, figs. 2–4.

One of the forms from Gaspé was identified with Raymond's species after comparison with casts of the tvpes. The excellent material illustrated, combined with the generic description, shows most of its features. This species is characterized by the relatively long and narrow glabella, straight-sided for the posterior half and expanding forwards. The pygidium has a very prominent axis that almost overhangs the posterior rim.

The largest cephala observed have a length of 5 mm.

The specimens illustrated are from boulder G-28, Grosses Roches.

Plesiotypes: Laval University nos. 1012 a–p.

CEPHALOCOELIA ROTUNDA Rasetti, n. sp.
Plate 68, figures 18–23

This species too is represented by perfectly preserved cephala, cranidia and pygidia. Owing to its great similarity to *C. lata*, it will best be described by comparison with the latter. The glabella is definitely wider and shorter, hence more hemispherical. In side view there is practically no difference between the cephala of the two species. The pygidium has a distinctly less prominent axis than in *C. lata*, especially at the posterior end, where the axis does not overhang the rim but leaves it well visible from above.

The largest cranidium, out of several scores observed, has a length of 6.5 mm.; the largest pygidium a length of 4.5 mm. and a width of 6 mm.

The types are from boulder M-17, Métis.

Holotype and paratypes: Laval University nos. 1013 a–p.

CEPHALOCOELIA IMPRESSA Rasetti, n. sp.
Plate 68, figures 1–8

This species is closely similar to the two preceding ones, differing essentially in the relatively wider and shorter glabella. The sides of the glabella are more regularly curved, so that the outline of the glabella, including the occipital ring, forms almost a circle. The occipital furrow is less straight than in *C. lata* and *C. rotunda*, and instead of possessing almost uniform width, is deeper and wider at the sides than mesially. The latter character separates the species also from *C. ovoides*, which it greatly resembles in all other respects.

The pygidium has a very prominent axis, and can hardly be distinguished from that of *C. lata*.

Length of largest cephalon 5 mm.

Boulders G-40 and G-18, Grosses Roches (holotype from the former).

Holotype and paratypes: Laval University nos. 1014 a–r.

CEPHALOCOELIA? SIMPLEX (Raymond)
Plate 68, figures 24–27

Ucebia simplex RAYMOND, 1937, Geol. Soc. America Bull., vol. 48, p. 1103, pl. 2, fig. 5.

A few cranidia recovered from the conglomerates in Gaspé seem to agree with Raymond's type in all respects. The new material shows several characters of the species that are not apparent from the type. One feature is the presence in front of the glabella of a very narrow rim, which appears to be broken off in Raymond's specimen. This character does not occur in the typical species of *Cephalocoelia* and hence the present form is assigned to the genus with doubt. However, it fits better in *Cephalocoelia* than in any other described genus.

The palpebral lobes are even narrower than in other species of *Cephalocoelia*, but the ocular ridges, contrary to what is observed in the other species, are distinct. The occipital ring is extended into a sharp horizontal spine. The whole surface of the cranidium is granulated, whereas that of the other species is smooth. An unusually large cranidium has a length of 4 mm., but the others observed are much smaller.

From the characters described it will appear that this species has features in com-

mon with *Cephalocoelia*, *Distazeris* and *Madarocephalus*. The general shape of the cranidium is more suggestive of *Cephalocoelia*, but the narrow brim occurs in *Distazeris*, and the occipital spine in the latter genus and in *Madarocephalus*.

Boulders G-18 and G-40, Grosses Roches.

Plesiotypes: Laval University nos. 1015 a–c.

Genus COOSELLA Lochman, 1936

COOSELLA GRANULOSA Rasetti, n. sp.

Plate 68, figure 31

Cranidium of moderate convexity. Glabella tapered, rounded in front, unfurrowed. Dorsal furrow deep all around the glabella. Occipital furrow deep laterally but very shallow mesially. Fixed cheeks about one-third the glabellar width at the palpebral lobes. The latter are narrow, rather strongly curved, set off from the fixed cheeks by a shallow furrow. Anterior branch of facial suture directed almost straight forward, curving inward and crossing the rim obliquely as in other species of the genus. Rim strongly convex; preglabellar area equaling the rim in width. Posterior branch of facial suture directed strongly outward, then curving backward. Posterolateral limbs with a deep intramarginal furrow.

Surface of cranidium covered with fairly large elevated granules. Three pairs of smooth areas at the sides of the glabella mark the position of the obsolete glabellar furrows. The rim has smaller granules than the glabella on its posterior half; the anterior half has no granules but is transversely striated.

Length of holotype cranidium 10 mm.

This species is typical of the genus but differs from all those described in the coarser surface ornamentation.

Boulder G-28, Grosses Roches.

Holotype and paratype: Laval University nos. 1016 a–b.

COOSELLA sp. undet.

Plate 68, figure 32

Only pygidia were recovered. Pygidium subrectangular, with little relief owing to the flatness of the pleural lobes. Axis prominent, cylindrical, occupying half the length of the pygidium; composed of four rather poorly defined segments. Pleural lobes slightly concave as a whole. Pleural furrows well impressed near the axis, shallow distally but almost reaching the margin. Five pairs of furrows are visible, the second and third pairs being accompanied by interpleural grooves that are close to the respective furrows near the axis, become separate for some distance, and again merge with the wide shallow furrows distally. Lateral outline of the pygidium almost straight; posterior outline slightly concave mesially; posterolateral angles right, scarcely rounded. Surface finely granulated.

This pygidium resembles that of *C. helena* Lochman, but it has a more rectangular shape and the pleural furrows extend for a greater distance. It may belong to *C. granulosa*, but since the pygidium and cranidium were not found associated in the same boulder the writer prefers to refrain from assigning it to that species.

Boulder G-30, Grosses Roches.

Figured specimen: Laval University no. 1017 a.

Genus CRYPTODERASPIS Rasetti, n. gen.

Known from the cranidium alone. Glabella strongly convex, oval, unfurrowed, extending backward beyond the narrow occipital segment, which therefore is not visible from above. Fixed cheeks and brim convex, lying entirely below the level of the dorsal furrow. Rim absent. Fixed cheeks about half as wide as the glabella; palpebral lobes very small, situated much in advance of the glabellar midpoint; ocular ridges present. Anterior facial sutures approximately parallel; posterior branch straight, defining rather large, triangular posterolateral limbs which lack an intramarginal furrow.

Genotype: *Cryptoderaspis metisensis* Rasetti, n. sp.

Remarks.—The writer has been unable to find any described trilobite showing sufficient similarity to the present form to suggest a possible affinity. The rearward extension of the glabella and the sloping brim constitute an unusual combination of characters.

CRYPTODERASPIS METISENSIS Rasetti, n. sp.

Plate 68, figures 28–30

The generic description and the illustrations present all that is known of this spe-

cies. A few cranidia were recovered from one boulder. The length of the largest cranidium is 6.5 mm. The surface is smooth.

Boulder M-7, Métis.

Holotype and paratype: Laval University nos. 1018 a–d.

Genus HEMIRHODON Raymond, 1937

This genus occurs in several of the boulders, and its associations seem to indicate that there are both Middle and Upper Cambrian species. This is one of the very few genera that range through the Middle-Upper Cambrian boundary.

Two species, whose associations definitely indicate a Dresbach age, are described.

HEMIRHODON EMARGINATUS Rasetti, n. sp.
Plate 69, figures 4–7

Glabella moderately convex, long and narrow, almost straight-sided, expanding toward the front, unfurrowed. Dorsal furrows becoming very shallow in front of the anterior pits, which are fairly well impressed. Occipital furrow wide and shallow. Brim absent; anterior outline of cranidium somewhat pointed. Palpebral lobes small, distant from the glabella about one-sixth of the glabellar width. Fixed cheeks maintaining an approximately even width in front of the eyes. Posterior branch of the facial suture directed outwards and backwards, moderately curved, defining large subtriangular posterolateral limbs. Intramarginal furrow wide and shallow.

Associated pygidium with a narrow, tapered axis occupying two-thirds of the length. Axis continued by a narrow postaxial ridge that almost reaches the posterior edge. Axis faintly furrowed, composed of four segments plus a terminal section. Pleural lobes depressed, slightly convex mesially and concave marginally. Four pairs of pleural furrows are well impressed, and three pairs of interpleural grooves are also visible, although slightly shallower than the furrows. The posterior margin of the pygidium has a distinct mesial notch; the remaining outline is regularly rounded.

Length of cranidium 8 mm. The largest pygidium is 8 by 12 mm. Surface smooth.

This species differs from those described by Raymond in the complete absence of glabellar furrows. It is not certain whether the species described by Raymond from Vermont are of Middle or Upper Cambrian age. By their extreme resemblance to Mid-

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EXPLANATION OF PLATE 69

The test is preserved in all the figured specimens unless otherwise indicated.

FIGS. *1–3—Hemirhodon simplex* Rasetti, n. sp. *1*, Cranidium, ×1.5; Laval U. 1020c, paratype. *2*, Pygidium, ×1.5; Laval U. 1020a, holotype. *3*, Small pygidium, ×3; Laval U. 1020b, paratype. (p. 453)

4–7—Hemirhodon emarginatus Rasetti, n. sp., ×2. *4*, *5*, Top and side views of cranidium; Laval U. 1019a, holotype. *6*, *7*, Pygidia; Laval U. 1019b–c, paratypes. (p. 452)

8–13—Homodictya imitatrix Raymond, ×3. *8*, *9*, Top and side views of cranidium. *10*, *11*, Top and side views of another cranidium. *12*, *13*, Pygidia; Laval U. 1022a–d, plesiotypes. (p. 454)

14, *15*—Undetermined pygidium, ×1.5. Top and side views of specimen; Laval U. 1041a. (p. 462)

16—Holcacephalus cf. *H. tener* (Walcott), ×8. Cranidium; Laval U. 1021. (p. 454)

17–22—Kingstonia gaspensis Rasetti, n. sp. *17*, *18*, Side and top views of cranidium, ×4; Laval U. 1023a, holotype. *19*, Large exfoliated cranidium, ×2. *20*, Exfoliated pygidium, ×2; *21*, *22*, Side and top views of pygidium, ×2; Laval U. 1023b–d, paratypes. (p. 454)

23, *24—Kingstonia walcotti* Resser, ×4. *23*, Cranidium. *24*, Pygidium; Laval U. 1024a–b, plesiotypes. (p. 455)

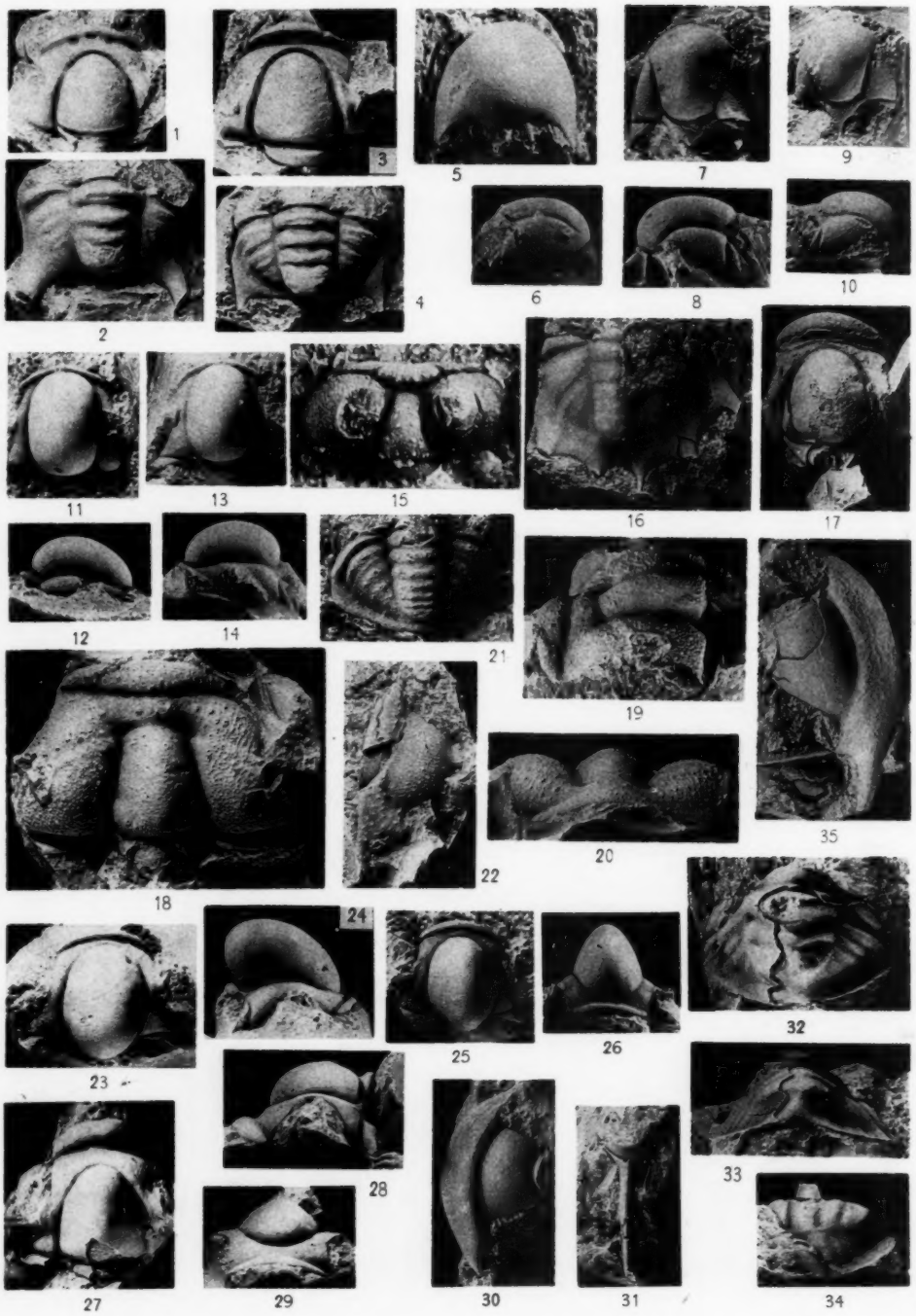
25–31—Kingstonia quebecensis Rasetti, n. sp., ×4. *25*, *26*, Top and front views of cranidium; Laval U. 1025a, holotype. *27*, Cephalon preserving the right free cheek. *28*, *29*, Top and side views of another cranidium. *30*, *31*, Side and top views of pygidium; Laval U. 1025b–d, paratypes. (p. 455)

32–34—Kormagenostus simplex Resser. *32*, Pygidium, ×6. *33*, *34*, Cephala, ×5; Larval U. 1001a–c, plesiotypes. (p. 444)

35, *36—Lecanopleura? punctata* Rasetti, n. sp., ×3. Top and side views of cranidium; Laval U. 1026a, holotype. (p. 456)

37, *38—Lecanopleura? tuberculata* Rasetti, n. sp., ×4. Top and side views of cranidium; Laval U. 1027a, holotype. (p. 457)

Rasetti, Upper Cambrian Trilobites



Rasetti, Upper Cambrian Trilobites

dle Cambrian species from Gaspé, the writer inclines towards the former hypothesis.

Raymond incorrectly described the pygidium of *Hemirhodon* by stating that in *H. viator* "the pleural lobes bear six pairs of low but well-defined ribs, separated by narrow furrows." As it appears from an examination of the types, as well as from the inspection of Raymond's figure, there are four pairs of pleural furrows and three pairs of interpleural grooves, both sets being about equally impressed. Nevertheless, the fact that only alternating furrows are homologous is unmistakable, especially when one compares the pleural furrows with the axial furrows. Pleural furrows and interpleural grooves have often been confused in the literature, although usually there is not the slightest difficulty in distinguishing the two, even when the pygidium is not attached to the thorax. In *Hemirhodon* both pleural furrows and interpleural grooves are about equally impressed, the grooves dividing equally the spaces between the furrows, at least distally. Near the axis each furrow is closer to the preceding interpleural groove, in accordance with the oblique course of the pleural furrow in the proximal part of the thoracic pleura.

Boulder G-28, Grosses Roches.

Holotype and paratypes: Laval University nos. 1019 a–d.

HEMIRHODON SIMPLEX Rasetti, n. sp.
Plate 69, figures 1–3

A second species of *Hemirhodon* is represented in several boulders of Dresbach age.

Cranidium with less relief than in the preceding species. Glabella weakly convex with slightly concave sides, unfurrowed. The only available cranidium is incomplete and other characters are not clearly determinable.

Pygidium regularly semicircular, without a mesial notch. Axis low, tapered, with five or six faintly defined segments; occupying two-thirds of the pygidial length. Pleural lobes slightly concave, with four pleural furrows and three interpleural grooves, all wide and shallow, almost reaching the margin.

Length of cranidium 17 mm. The largest pygidium has a length of 14 mm. and a width of 24 mm. Surface smooth.

This species differs from the preceding in the proportionately shorter and wider glabella, and especially in the shape of the pygidium. The cranidium differs from those of Raymond's species in the total absence of glabellar furrows. The pygidium is almost identical with that assigned to *H. schucherti* by Raymond. A Middle Cambrian species from Gaspé also has a similar pygidium.

Boulder M-17, Métis.

Holotype (pygidium) and paratypes: Laval University nos. 1020 a–g.

EXPLANATION OF PLATE 70

The test is preserved in all the figured specimens unless otherwise indicated.

FIGS. *1, 2—Tricrepicephalus* sp. undet. no. 1. *1*, Exfoliated cranidium, ×2; Laval U. 1038. *2*, Exfoliated pygidium, ×1.5; Laval U. 1039. (p. 461)

3, 4—Meteoraspis borealis Lochman, ×2. *3*, Exfoliated cranidium; Laval U. 1032a. *4*, Exfoliated pygidium; Laval U. 1033a; plesiotypes. (p. 458)

5—Leiocoryphe? prisca Rasetti, n. sp., ×6. Cranidium; Laval U. 1028, holotype. (p. 457)

6–10—Madarocephalus minor Rasetti, n. sp., ×6. *6*, Side view of cephalon; Laval U. 1029b, paratype. *7, 8*, Top and side views of cranidium; Laval U. 1029a, holotype. *9, 10*, Top and side views of another cranidium; Laval U. 1029c, paratype. (p. 457)

11–14—Matania ovata Rasetti, n. gen., n. sp., ×6. *11, 12*, Top and side views of cranidium; Laval U. 1030b, paratype. *13, 14*, Top and side views of another cranidium; Laval U. 1030a, holotype. (p. 458)

15—Menomonia semele (Walcott), ×8. Cephalon; Laval U. 1031, plesiotype. (p. 458)

16—Olenoides? trispinosus Rasetti, n. sp., ×2. Pygidium; Laval U. 1035a, holotype. (p. 459)

17—Tricrepicephalus sp. undet. no. 2, ×1.5. Exfoliated cranidium; Laval U. 1040. (p. 462)

18–22—Metisaspis hispida Rasetti, n. gen., n. sp. *18–20*, Top, side and front views of cranidium, ×2; Laval U. 1034a, holotype. *21*, Pygidium, ×3; Laval U. 1034b, paratype. *22*, Free cheek, ×2; Laval U. 1034c, paratype. (p. 459)

23–26—Onchonotopsis pergibba Rasetti, n. gen., n. sp., ×6. *23, 24*, Top and side views of cranidium; Laval U. 1036a, holotype. *25, 26*, Top and front views of another cranidium; Laval U. 1036b, paratype. (p. 460)

27–35—Shickshockia cristata Rasetti, n. gen., n. sp. *27–29*, Top, side and front views of cranidium, ×2.5; Laval U. 1037a, holotype. *30*, Free cheek, ×2.5. *31*, Axial spine of a thoracic segment, ×1.5. *32–34*. Top, back and side views of partly exfoliated pygidium, ×2.5. *35*, Large free cheek, ×1.5; Laval U. 1037b–e, paratypes. (p. 461)

Genus HOLCACEPHALUS Resser, 1938

HOLCACEPHALUS cf. H. TENER (Walcott)

Plate 69, figure 16

Norwoodia tenera WALCOTT, 1916, Smithsonian Misc. Coll., vol. 64, no. 3, p. 172, pl. 28, figs. 2–2g.

Norwoodia tenera Walcott. LOCHMAN, 1938, Jour. Paleontology, vol. 12, p. 83, pl. 18, figs. 11–13.

Holcacephalus granulatus RESSER, 1938, Geol. Soc. America Special Papers 15, p. 81, pl. 9, figs. 15–17.

Norwoodina tenera (Walcott). LOCHMAN, 1940, Jour. Paleontology, vol. 14, p. 50, pl. 5, figs. 12–14.

Holcacephalus tenerus (Walcott). LOCHMAN and DUNCAN, 1944, Geol. Soc. America Special Papers 54, p. 137, pl. 13, figs. 15–17.

Specimens of *Holcacephalus* occur in several of the boulders. They do not appear to differ significantly from *H. tener*, but since they are small and only moderately well preserved, the assignment to the species cannot be certain.

The figured specimen (Laval University no. 1021) is from boulder G-18, Grosses Roches.

Genus HOMODICTYA Raymond, 1937

Raymond's succinct diagnosis of the genus is "Tsinanidae (?) with marginal suture and small eyes in front of the middle." The writer believes that a clearer understanding of *Homodictya* can be gathered from a comparison with the common North American genus *Blountia*, to which it is extremely similar and closely related. The cranidium of *Homodictya* is typical of *Blountia* in all respects, excepting the entire obliteration of the anterior furrow and the somewhat stronger divergence of the facial sutures in front of the eyes.

Raymond assigned to *Homodictya imitatrix* a pygidium that in the writer's opinion does not belong to it. Association in the conglomerate boulders in several instances leaves no doubt that the true pygidium of *Homodictya* is indistinguishable generically from the pygidia of *Blountia*.

HOMODICTYA IMITATRIX Raymond

Plate 69, figures 8–13

Homodictya imitatrix RAYMOND (part), 1937, Geol. Soc. America Bull., vol. 48, p. 1114, pl. 3, fig. 7 (not fig. 8).

The new well-preserved material available allows a more complete description of this species.

Cranidium of fairly strong convexity as a whole. Glabella rather strongly arched in both directions, tapered, unfurrowed. Occipital furrow extremely shallow, occipital ring very narrow. Dorsal furrow narrow and shallow all around the glabella. Fixed cheeks much lower than the glabella, moderately convex. Palpebral lobes small, narrow, unfurrowed, distant from the glabella less than one-third of the glabellar width, situated somewhat in advance of the glabellar midpoint. Facial sutures diverging strongly in front of the eyes, then turning inward in a wide curve and becoming marginal for a considerable distance. The marginal course of the suture is evidenced by the fact that the rim has a low, transversely striated, vertical face. The posterior half of the brim slopes downward, but the anterior half is progressively upturned because of its regularly concave profile. There is no trace of an anterior furrow, hence the brim is not divided into rim and preglabellar area. The posterior branch of the facial suture is directed outward and backward and is regularly curved, defining moderately wide posterolateral limbs. These are narrowly rounded at the extremity and possess a shallow intramarginal furrow.

Pygidium of the *Blountia* type, very depressed. Axis depressed, defined by shallow dorsal furrows, tapered, occupying two-thirds of the pygidial length; axial furrows indistinct. Pleural lobes flat; rim width at the rear one-third the length of the pygidium; somewhat less at the sides. The rim is hardly set off by a furrow or by an appreciable change in slope, but is only distinguishable because the trace of segmentation that is apparent on the remaining surface of the pleural lobes does not extend across it. The width of the rim corresponds to the extent of the doublure.

Surface of both shields smooth. Length of largest cranidium observed 7 mm.

Boulders G-3 and G-30, Grosses Roches.

Plesiotypes: Laval University nos. 1022 a–r.

Genus KINGSTONIA Walcott, 1924

KINGSTONIA GASPENSIS Rasetti, n. sp.

Plate 69, figures 17–22

This is a common species, known from a large number of associated cranidia and pygidia.

Cranidium rather strongly convex longitudinally, the convexity strongest in the middle. Glabella faintly defined all around even on the outer surface; dorsal furrows somewhat more distinct along the posterior third of the glabella. Glabella almost parallel-sided, occupying about four-fifths of the cranidial length. Occipital furrow exceedingly shallow, occipital segment very narrow. Brim continuing the slope of the glabella, weakly convex; anterior portion characterized by several weak transverse ridges, without any differentiated rim. Palpebral lobes small, distant from the glabella less than the width of the brim, situated at one-fifth the distance between the front end of the glabella and the posterior margin of the cephalon. Facial sutures slightly converging in front of the eyes, then curving inward and producing a rounded outline of the brim. Posterior branches almost straight from the eye to the posterior margin, defining relatively narrow, long posterolateral limbs, which extend considerably farther back than the mesial portion of the head. Posterior outline of the posterolateral limbs slightly concave. Intramarginal furrow impressed on the cast of the lower surface in the proximal portion, entirely obsolete on the upper surface of the test.

Pygidium subtriangular, but widely and regularly rounded posteriorly, almost flat in its mesial portion, but attaining considerable relief through the downfolding of the margin all around. The margin thus attains a vertical slope and is even slightly underfolded. All the furrows are wanting on the outer surface. The cast of the inner surface shows fairly well impressed dorsal furrows defining an axis that occupies about one-third of the pygidial width. The whole length of the axis shows faint furrows, defining seven or eight segments. There are also several very faint pleural furrows.

The outer surface is smooth, the cast of the lower surface punctate.

This is a large species for the genus. Cranidia of various sizes up to 11 mm. in length and 17 mm. in width were observed. The largest pygidium has a length of 10 mm., a width of 14 mm.

Of all the species described, only *K. alabamensis* Resser and *K. mucro* Resser appear closely to resemble the present one, but both have a wider cranidium, and the posterolateral limbs are wider and directed more transversely.

Boulder G-28, Grosses Roches.

Holotype and paratypes: Laval University nos. 1023 a–z.

KINGSTONIA WALCOTTI Resser
Plate 69, figures 23, 24

Kingstonia walcotti RESSER, 1938, Geol. Soc. America Special Papers 15, p. 83, pl. 12, figs. 3, 4.

Kingstonia walcotti Resser. LOCHMAN, 1940, Jour. Paleontology, vol. 14, p. 35, pl. 4, figs. 13–16.

Kingstonia walcotti Resser. LOCHMAN and DUNCAN, 1944, Geol. Soc. America Special Papers 54, p. 113, pl. 14, figs. 21–26.

A species of *Kingstonia* that occurs in several boulders was carefully compared with specimens of *K. walcotti* from Missouri and Montana kindly supplied to the writer by Dr. Lochman, and both the cranidium and pygidium appear to be identical.

A cranidium and pygidium from boulder G-28, Grosses Roches are illustrated.

Plesiotypes: Laval University nos. 1024 a–l.

KINGSTONIA QUEBECENSIS Rasetti, n. sp.
Plate 69, figures 25–31

This species is represented by abundant and well-preserved material.

Cranidium relatively wide and short. Convexity in longitudinal section rather strong, approximately uniform excepting near the posterior border, where it is stronger. Dorsal furrows entirely obsolete on the outer surface. On the cast of the inner surface the dorsal furrows are fairly deep posteriorly but die out at half the distance from the posterior margin, so that even in this case the glabella is not defined in front. Occipital furrow entirely obsolete on the outer surface, but visible on exfoliated cranidia, where it defines a very narrow occipital ring. Palpebral lobes short and narrow, situated at less than one-third of the distance from the anterior to the posterior margin of the head. Anterior branch of the facial sutures straight, directed inward and crossing the rim obliquely. Rim not much elevated but quite distinct, transversely striated, moderately curved. Posterior branch of the facial suture directed first outward and slightly backward, then curving more definitely backward and becoming nearly straight before reaching the posterior

margin. Posterolateral limbs of average size, narrowly rounded at the ends. Posterior outline of the neck segment well curved, reaching farther back than the posterolateral limbs. Intramarginal furrow on the posterolateral limbs obsolete on the outer surface but impressed on the cast of the interior.

A cranidium preserves one of the free cheeks and the eye. The free cheek is very narrow, and the posterior branch of the facial suture reaches the margin just short of the genal angle. The latter is rounded, genal spines being absent. The eye is but little elevated above the surface of the head.

The pygidium is relatively wide and short, and the posterior outline forms an almost perfect semicircle. The whole of the pygidium is depressed mesially and becomes convex near the border, especially in the posterior part, where the margin attains a vertical slope. The axis is fairly well defined at the sides even on the upper surface, but its posterior end merges with the pleural lobes. Axis and pleural lobes appear smooth on the outer surface, but show faint furrows when exfoliated.

Surface of test smooth; surface of cast of the interior finely punctate.

Size of largest cranidium 4.5 by 7.2 mm., of largest pygidium 3.1 by 4.6 mm.

This species, although quite average in shape for the genus, appears distinct from all those described, unless it be identical with one of those described by Resser from the southern Appalachians and which are too imperfectly known for specific identification in such a prolific genus. The cranidium is not unlike that of the genotype, *K. apion* Walcott, but is much wider and shorter. The cranidium alone resembles more that of *K. spicata* Lochman, but the pygidium is entirely different. *K. walcotti* has a much more globular cranidium, although there is little difference in the pygidia. Finally, a species that closely resembles the present one is *K. vagrans* Lochman from Newfoundland, which differs in the more uniform longitudinal convexity of the cranidium, and especially in the different course of the posterior branch of the facial sutures. There appears to be little difference in the pygidia.

A species of *Kingstonia* which is one of the most common fossils in the Murphy Creek formation of eastern Gaspé seems to be identical with the present form.

Boulder G-29, Grosses Roches.

Holotype and paratypes: Laval University nos. 1025 a–v.

Genus LECANOPLEURA Raymond, 1937

LECANOPLEURA? PUNCTATA Rasetti, n. sp.

Plate 69, figures 35, 36

Cranidium rather strongly convex as a whole. Glabella strongly convex, tapered, rounded in front, unfurrowed. Circumglabellar furrow narrow and deep. Occipital furrow narrow but well impressed, occipital ring simple, of average width. Fixed cheeks convex, rising somewhat above the level of the dorsal furrows. Palpebral lobes small, narrow, indistinctly furrowed; situated in advance of the glabellar midpoint and distant from the glabella one-third of the glabellar width. Brim of moderate width, convex. Rim moderately convex, upturned, narrower than the preglabellar area. Anterior furrow with a series of distinct puncta. Anterior facial sutures rather strongly divergent, straight to the anterior furrow and then crossing the rim obliquely. Posterior branch directed straight outward and backward for a considerable distance, then curving sharply backward. Posterolateral limbs strongly furrowed. Surface of test apparently smooth, excepting a few faint tubercles on the fixed cheeks.

Length of holotype cranidium 7 mm., width between the tips of the posterolateral limbs 8.5 mm.

Although this species closely resembles the genotype, *L. interrupta* Raymond from the Rockledge of Vermont, nevertheless it is doubtfully assigned to the genus, since cranidia of this type are common through the entire Middle and Upper Cambrian, and more should be known of the other parts of the shield before the genera are properly understood. The present form fits better in *Lecanopleura* than in any other described Upper Cambrian genus. It differs from the two species described by Raymond chiefly in the deeper dorsal furrows and the wider brim.

Boulder G-28, Grosses Roches.

Holotype and paratypes: Laval University nos. 1026 a–c.

LECANOPLEURA? TUBERCULATA Rasetti, n. sp.
Plate 69, figures 37, 38

This species, also known only from the cranidium, is so similar to the preceding that it may best be described by comparison with it. The only apparent differences from *L.? punctata* are the narrower preglabellar area, causing the rim to be slightly wider mesially than the preglabellar area itself; the slightly more posterior position of the palpebral lobes; and chiefly the character of the surface. The prominent part of the glabella is marked with fairly large, rather widely spaced tubercles. Similar tubercles, but less prominent, are scattered on the fixed cheeks and the posterior half of the rim. The anterior portion of the rim is transversely striated. There is a row of puncta in the anterior furrow as in the preceding species.

Length of holotype cranidium 5 mm., width between the tips of the posterolateral limbs 6.5 mm.

Boulder M-17, Métis.

Holotype and paratype: Laval University nos. 1027 a–b.

Genus LEIOCORYPHE Clark, 1924
LEIOCORYPHE? PRISCA Rasetti, n. sp.
Plate 70, figure 5

A peculiar cranidium that occurs in association with Dresbach fossils is tentatively assigned to this late Upper Cambrian genus. It agrees with the genotype in all essential respects, but it must be understood that it is difficult to evaluate the affinities of such a featureless cranidium. It is possible that if the other parts of the shield were known the species should be assigned to a new genus.

Cranidium somewhat wider than long, strongly and almost uniformly convex, lacking all furrows. Anterior outline regularly semicircular. Posterolateral limbs extended rather far backward, pointed. Posterior margin slightly extended backward mesially. The lateral margin of the shield is regularly curved, hence it is not quite certain whether the specimen represents an entire cephalon or the cranidium alone. In either case, it is certain that there are no eyes or palpebral lobes. The writer inclines to believe that the free cheeks are lacking, since there appears to be no doublure. In the late Upper Cambrian species of the genus isolated cranidia may easily be mistaken for complete cephala, owing to the lack of palpebral lobes and of a sharp angle between the posterior and anterior branches of the facial sutures.

The cranidium of this species has about the same proportions as in *L. gemma* Clark, but in the latter species a trace of the occipital furrow is visible.

Length of holotype cranidium 2.5 mm., width 3.5 mm. Surface smooth.

Boulder M-17, Métis.

Holotype: Laval University no. 1028.

Genus MADAROCEPHALUS Resser, 1938

The conglomerates at Métis yielded a species of *Madarocephalus*, represented by better-preserved material than that used by Resser to describe the genus. Hence a more complete diagnosis can be given.

Glabella straight-sided, expanded toward the front, occupying the whole cranidial length. Glabellar furrows absent; occipital furrow well impressed. Occipital segment bearing a sharp, horizontally directed spine. Brim absent; palpebral lobes short and narrow, opposite the anterior third of the glabella, and extremely close to the dorsal furrows. Hence the anterior fixed cheeks are practically wanting. Posterolateral limbs large, triangular, with a well-impressed intramarginal furrow. The posterior branch of the facial suture seems to reach the margin in advance of the genal angle, hence this trilobite should apparently be considered as proparian, as already suspected by Resser. The suture in front of the cranidium is somewhat intramarginal but is not visible from above on account of the great convexity of the anterior portion of the cephalon.

MADAROCEPHALUS MINOR Rasetti, n. sp.
Plate 70, figures 6–10

The generic description and the illustrations present most of the characters of this species. One cephalon preserves the right free cheek, but unfortunately the course of the posterior branch of the facial suture cannot be clearly seen. However, the fact that the genal angle does not extend farther back in this specimen than in cranidia lacking the free cheeks, suggests that the suture reaches the margin in advance of the genal angle.

Some of the specimens show a trace of glabellar furrows in the shape of short pits. It is difficult to establish a close comparison between the Métis form and the genotype, *M. laetus* Resser from the southern Appalachians, as the latter was described from flattened specimens, whereas the cranidia of *M. metisensis* preserve their full convexity. Comparison with Resser's types does not seem to indicate any significant difference except in size, none of the cranidia from Métis exceeding 3 mm. in length.

Boulder M-1, Métis.

Holotype and paratypes: Laval University nos. 1029 a–g.

Genus MATANIA Rasetti, n. gen.

Small trilobites known from the cranidium. Glabella occupying most of the cranidial area, strongly convex, oval, unfurrowed. Occipital furrow deep, occipital segment narrow and simple. Fixed cheeks narrow, much lower than the glabella. Palpebral lobes small, distant from the glabella but a small fraction of the glabellar width and opposite the glabellar midpoint. Anterior facial sutures hardly divergent: brim reduced to a narrow convex rim. Posterior branch of facial suture straight, defining fairly wide, triangular posterolateral limbs.

Genotype: *Matania ovata* Rasetti, n. sp.

Remarks.—The tumid glabella of this trilobite suggests a superficial resemblance to *Onchonotus*, but the structure of the brim is different and the palpebral lobes are much narrower. The genus is possibly more closely related to *Onchonotopsis*, from which it differs in the absence of a preglabellar area and the much lesser tumidity of the glabella. The real affinities of this trilobite for the present remain obscure.

MATANIA OVATA Rasetti, n. sp.
Plate 70, figures 11–14

The generic description and the illustrations present all the known characters of the cranidium of this species. The length of the largest cranidia is 3.5 mm. The surface is smooth.

Boulder G-18, Grosses Roches.

Holotype and paratypes: Laval University nos. 1030 a–e.

Genus MENOMONIA Walcott, 1916
MENOMONIA SEMELE (Walcott)
Plate 70, figure 15

Millardia semele WALCOTT, 1916, Smithsonian Misc. Coll., vol. 63, no. 3, p. 163, pl. 28, figs. 3, 3a–c.

Menomonia semele (Walcott). RESSER, 1938, Smithsonian Misc. Coll., vol. 97, no. 10, p. 35.

Menomonia semele (Walcott). LOCHMAN and DUNCAN, 1944, Geol. Soc. America Special Papers 54, p. 135, pl. 14, figs. 10–13.

A single cephalon of *Menomonia* seems to agree with this species in all respects, particularly in the presence of the large granules on the glabella and rim. The presence of *M. semele* in Gaspé is remarkable, since the species was so far known only from the Cordilleran province.

Boulder G-28, Grosses Roches.

Plesiotype: Laval University no. 1031.

Genus METEORASPIS Resser, 1935
METEORASPIS BOREALIS Lochman
Plate 70, figures 3, 4

Meteoraspis borealis LOCHMAN, 1938, Jour. Paleontology, vol. 12, p. 472, pl. 56, figs. 1–5.

Meteoraspis borealis Lochman. LOCHMAN and DUNCAN, 1944, Geol. Soc. America Special Papers 54, p. 97, pl. 9, fig. 10.

A few cranidia of *Meteoraspis* fully agree with the species, originally described from Newfoundland and later reported from central Montana. All the available cranidia are exfoliated.

A pygidium of the *Meteoraspis* type is likely to belong with these cranidia, with which it occurs associated in one of the boulders. However, in another boulder the same pygidium was associated with cranidia referred to *Tricrepicephalus*, hence the assignment to the species is somewhat questionable. The pygidium has a subrectangular shape. Axis very strongly prominent, slightly tapered, with three deep furrows (besides the articulating furrow) and a terminal unsegmented section. Pleural lobes as wide as the axis, convex. Three pleural furrows of decreasing depth, with interpleural grooves visible on the cast of the interior. Border flat, extended into a pair of short, backward-directed spines at the posterior angles. Small pygidia preserving the test show that the prominent parts of the shield are granulated.

Figured specimens from boulder G-29, Grosses Roches.

Cranidia: Laval University nos. 1032 a–b; pygidia, Laval University nos. 1033 a–f.

Genus METISASPIS Rasetti, n. gen.

Glabella tapered, straight-sided, truncated in front, with faint furrows. Occipital furrow deep; characters of occipital ring poorly known. Fixed cheeks on the average as wide as the glabella, strongly convex, rising almost to the glabellar level. Palpebral lobes small, elevated, situated slightly back of the glabellar midpoint; palpebral ridges present. Anterior facial sutures slightly divergent in front of the eyes, curving gently inward and then crossing the rim obliquely. Brim divided into a convex preglabellar area and an equally wide, convex rim. Posterior branch of the facial suture directed at first outward and backward, then straight outward, defining rather long posterolateral limbs; the last portion directed straight backward. Free cheeks fairly convex, drooping steeply; with a wide convex rim. Genal spines present.

Pygidium rather strongly convex. Anterior margin curving backward and assuming a longitudinal course. Axis prominent, almost reaching the posterior margin, with distinct segments. Pleural lobes convex, furrowed. Rim distinct, wider at the sides.

Surface of all parts of the shield tuberculated or spinose.

Genotype: *Metisaspis hispida* Rasetti, n. sp.

Remarks.—This genus recalls certain Middle Cambrian forms, such as *Acrocephalops* and *Bolaspis*. The latter especially has many features in common with *Metisaspis*, but in *Bolaspis* the preglabellar area is much wider and forms a more distinct boss. Among Upper Cambrian trilobites, the one that seems most to resemble *Metisaspis* is *Pesaia exsculpta* Walcott and Resser from Novaya Zemlya. This was described as an "Ozarkian" trilobite, but its association with *Irvingella* shows that it is probably of Franconia age. Apparently in *Pesaia* the fixed cheeks are not so convex as in *Metisaspis*, nor is the strong surface ornamentation present.

METISASPIS HISPIDA Rasetti, n. sp.
Plate 70, figures 18–22

There remain only a few details to be added to the generic description. The dorsal furrows are deep along the sides of the glabella, and in particular are strongly impressed at the anterolateral angles in the form of a pair of pits. However, the furrow in front of the glabella is relatively shallow. The preglabellar area forms a slight boss. The rim is as wide mesially as the preglabellar area, but tapers in width at the sides. The anterior furrow is characterized by a pair of pits, separated from each other by a distance equal to the glabellar width at the anterior end. The surface of the test, excepting the deeper impressions, is covered with fine granules, among which are scattered larger tubercles. Some of these are broken off, suggesting the bases of spines.

The pygidium shows the same surface ornamentation as the cranidium. There are tubercles both on the axis and the pleural lobes. On the axis, there is a pair of tubercles on each of the six or seven segments that can be distinguished. The larger tubercles on the pleural lobes are regularly arranged on the ribs. The rim is densely covered with fine granules.

Length of largest (holotype) cranidium 16 mm. Length of pygidium 5 mm., width 7 mm.

Boulders M-7 and M-17, Métis (holotype from the former).

Holotype and paratypes: Laval University nos. 1034 a–d.

Genus OLENOIDES Meek, 1877
OLENOIDES? TRISPINOSUS Rasetti, n. sp.
Plate 70, figure 16

A peculiar trilobite of undoubted Dresbach age is unfortunately represented only by pygidia and is questionably assigned to this Middle Cambrian genus. Since other forms in this Dresbach fauna, such as *Hemirhodon* and *Metisaspis*, present marked Middle Cambrian affinities, it is not impossible that a species of *Olenoides* may have survived until the early Upper Cambrian. If the cranidium does not agree with *Olenoides* or *Kootenia*, the species does not fit in any described genus.

Pygidium fairly large, moderately convex as a whole. Axis rising above the pleural lobes, slightly tapered, occupying about four-fifths of the pygidial length. Five segments and a terminal section can be faintly distinguished. Pleural lobes moderately convex, with a concave marginal area. Anterior margin transverse for some distance, then turning obliquely backward, extended into a probably rather long spine. Another pair of spines are situated about halfway to the posterior end, and a third pair are closer to each other than to the spines of the second pair. The pleural lobes show, in accordance with the number of spines, three segments; first pleural furrow fairly well impressed, second shallow. Interpleural grooves very shallow and visible only distally.

The larger of the two available pygidia has a length of 16 mm. and a width of approximately 25 mm. Surface smooth.

The present pygidium agrees in all respects with the pygidia of *Olenoides*, excepting the fact that, as far as the writer knows, all the Middle Cambrian species of *Olenoides* have four or more pairs of spines. The species might perhaps with equal right be tentatively assigned to *Kootenia*, but the writer prefers to place it in *Olenoides* since the latter genus is known to range higher in the Middle Cambrian.

It may be pointed out that if the present species really belongs to *Olenoides*, this genus possesses the unique distinction among Cambrian trilobites of ranging from the late Lower Cambrian to the early Upper Cambrian. It is already known that the genera of the *Kootenia-Olenoides* group are exceptionally long-ranging. This extraordinary stratigraphic range is probably connected with the fact that *Kootenia* is one of the extremely few genera of Middle Cambrian trilobites common to the Atlantic and the Appalachian-Cordilleran provinces.

Boulder M-17, Métis.

Holotype and paratype: Laval University nos. 1035 a–b.

Genus ONCHONOTOPSIS Rasetti, n. gen.

Small trilobites known from the cranidium. Glabella large, oval, unfurrowed, extremely convex, extending backward and overhanging the narrow occipital segment. Brim narrow, with a narrow convex rim. Fixed cheeks narrow, sloping downward; palpebral lobes small, situated halfway between the anterior and posterior margins of the cranidium. Anterior facial sutures approximately parallel; posterior branch straight, defining triangular posterolateral limbs of average size. Intramarginal furrow impressed on posterolateral limbs.

Genotype: *Onchonotopsis pergibba* Rasetti, n. sp.

Remarks.—Raymond described as *Onchonotus eminens* a small cranidium from the Rockledge conglomerate which shows a certain resemblance to *Onchonotus* but differs in several characters, probably the most important being the structure of the brim. In *Onchonotus* the brim has a characteristic triangular shape, whereas in Raymond's species it presents the more usual uniform curvature. Moreover, we should hardly expect a species of Dresbach age to belong to a genus of late Trempealeau and early Canadian age. Hence the present genus is erected to receive Raymond's species, as well as an undoubtedly congeneric form collected by the writer.

ONCHONOTOPSIS PERGIBBA Rasetti, n. sp.
Plate 70, figures 23–26

In this species, the gibbosity of the glabella that characterizes *O. eminens* is carried still further. The glabella is extremely elevated in its posterior part, extending beyond the occipital segment. In top view, the glabella appears regularly elliptical in shape. The surface of the glabella is very finely punctate. Length of holotype cranidium 3 mm.

Boulder M-17, Métis.

Holotype and paratypes: Laval University nos. 1036 a–l.

Genus SHICKSHOCKIA Rasetti, n. gen.

Cranidium very convex as a whole. Glabella strongly convex, well defined by the dorsal furrow, tapered, unfurrowed. Occipital furrow deep; occipital segment extended into a strong upturned spine. Palpebral lobes rather small, close to the glabella and situated opposite its midpoint. Brim of medium width, strongly deflected downward; anterior facial sutures slightly divergent. Rim wide, convex, about equaling

in width the preglabellar area. Posterior branch of facial suture straight for some distance back of the eye, then turning abruptly backward to meet the posterior margin at a right angle. Free cheeks wide, with a wide, distinct rim and rather strong, cylindrical genal spines.

The thorax is characterized by a strong upright spine on the axis of each segment.

Pygidium short and wide, rather strongly convex. Axis wide, with a strong upright spine on the first segment; showing a second segment and a terminal section. A short postaxial ridge reaches the posterior margin, which is elevated mesially. Pleural lobes sloping rather steeply, showing shallow furrows and grooves and a smooth, concave border.

Genotype: *Shickshockia cristata* Rasetti, n. sp.

The name is derived from the Shickshock mountains of Gaspé.

Remarks.—The writer is unable to suggest close affinities for *Shickshockia* among described Upper Cambrian trilobites. The genus resembles several undescribed forms of Middle Cambrian age that occur in the conglomerates at Métis and Grosses Roches. The cranidium shows some resemblance to *Meteoraspis*, but the fixed cheeks slope down from the dorsal furrow instead of rising to form a rounded ridge all around the glabella; the pygidium is entirely unlike that of *Meteoraspis*. The row of strong upright spines on the occipital segment, thoracic segments, and first segment of the pygidium is a remarkable characteristic of the genotype.

SHICKSHOCKIA CRISTATA Rasetti, n. sp.
Plate 70, figures 27–35

Only a few details remain to be added to the generic description. The palpebral lobes are semicircular, very faintly furrowed, and their length is somewhat less than one-fourth of the length of the glabella. The anterior furrow is fairly deep at the sides, but shallower mesially: there is a suggestion of a pair of pits as in *Meteoraspis*.

The free cheeks are weakly convex but contribute to the relief of the head by their very steep inclination. The posterior branch of the facial suture reaches the margin well within the genal angle; the free cheek shows clearly an indentation that corresponds to the end of the posterolateral limb.

The surface of all parts of the shield is very finely granulose.

One boulder was filled with the remains of this species, but remarkably enough almost all the fragments were free cheeks and thoracic segments, only a few cranidia and pygidia having been recovered. The largest cranidium has a length of 10 mm. (exclusive of the occipital spine) but separated free cheeks indicate individuals of more than twice this size. The largest pygidium has a length of 8 mm., a width of 12 mm.

Boulder G-30, Grosses Roches.

Holotype and paratypes: Laval University nos. 1037 a–o.

Genus TRICREPICEPHALUS Kobayashi, 1935

TRICREPICEPHALUS sp. undet. no. 1
Plate 70, figures 1, 2

A species of *Tricrepicephalus* is represented by a few cranidia and a tentatively assigned pygidium. It is not named because of the uncertain relationship of the two parts of the shield.

Cranidium rather strongly convex for the genus. Glabella tapered, somewhat pointed in front, defined by a deep circumglabellar furrow. Fixed cheeks and brim convex. Width of brim one-third of the glabellar length. Pits in the anterior furrow well impressed. Rim as wide as the preglabellar area. Occipital segment without spine.

The pygidium has a strongly prominent axis, occupying one-third of the width. Three segments and a terminal section well defined on the axis. Pleural lobes convex, with a deep anterior intramarginal furrow and only another, shallow furrow and traces of one interpleural groove. Spines strong, of oval cross section, directed moderately outward and upward, of unknown length. All the specimens are exfoliated.

It should be mentioned that in one boulder the cranidia of this species did not occur with the pygidium just described, but rather with a few examples of the pygidium tentatively assigned to *Meteoraspis borealis*. The number of specimens being too small to give much significance to this association, the writer prefers to group the two pygidia and the two cranidia in question according to the

well-established characters of the pygidia of *Meteoraspis* and *Tricrepicephalus*.

The present species appears very close to *T. comus* (Walcott) and *T. paracomus* Lochman in most of the features of both shields; this is an argument in favor of the assignment of pygidium and cranidium to one species.

The figured specimens are from boulder G-29, Grosses Roches.

Figured specimen (cranidium): Laval University no. 1038; pygidium, Laval University no. 1039.

TRICREPICEPHALUS sp. undet. no. 2
Plate 70, figure 17

A second species of *Tricrepicephalus* is represented by one exfoliated cranidium. It belongs to the group of species with an occipital spine, and appears closely to resemble *T. tripunctatus* (Whitfield).

Boulder G-3, Grosses Roches.

Figured specimen: Laval University no. 1040.

UNDETERMINED TRILOBITE PYGIDIUM
Plate 69, figures 14, 15

A peculiar, large pygidium does not fit in any described genus, but is not named, as the writer does not believe that trilobite genera should be based on pygidia, excepting under very unusual circumstances.

Whole pygidium strongly convex. Axis convex, occupying one-third of the width and three-fourths of the length; possessing, besides the articulating furrow, three furrows of decreasing depth and a terminal, rounded section. Pleural lobes strongly convex, without rim. Outline of pygidium subtrapezoidal, owing to the almost straight posterior margin. Only the anterior intramarginal furrow impressed on the pleural lobes.

Length of larger pygidium 14 mm., width 25 mm. Surface smooth.

This pygidium somewhat resembles a pygidium of *Meteoraspis* or *Tricrepicephalus*, but lacks spines. No corresponding cranidium was recovered from the same boulder.

Boulder G-30, Grosses Roches.

The described specimens are designated as Laval University nos. 1041 a–b.

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JOURNAL OF PALEONTOLOGY, VOL. 20, NO. 5, PP. 463–478, PLS. 71, 72, 4 TEXT FIGS., SEPTEMBER 1946

SIPHOGENERINOIDES CUSHMAN (ORDER FORAMINIFERA, FAMILY BULIMINIDAE)

BENTON STONE
International Petroleum Company, Negritos, Talara, Peru

ABSTRACT—*Siphogenerina* Schlumberger, 1882, and *Siphogenerinoides* Cushman, 1927, currently are diagnosed as triserial and biserial, respectively, in the initial stages of their microspheric generations. Thin sections and decorticated specimens show both to be triserial in that form. They are differentiated, however, by the circular aperture inclosing the siphon in *Siphogenerina*, as opposed to the reniform aperture of *Siphogenerinoides*, which does not inclose the siphonal orifice. Typical species of *Siphogenerinoides* are restricted to the Upper Cretaceous. Related forms in the lower Tertiary tentatively are placed in a new subgenus. Four new species and one new variety are described from the Upper Cretaceous of northwestern Peru.

INTRODUCTION

THE EXTERNAL appearance of Foraminifera of the genera *Siphogenerina* Schlumberger (1882) and *Siphogenerinoides* Cushman (1927) is so similar as to suggest a close relationship between these two forms. This paper discusses the internal structural and apertural characteristics of these two genera, as shown by a detailed thin-section study. Unfortunately, few authors have devoted much consideration to a detailed description of the internal structure of their specimens of these genera. Furthermore, specific determinations of some species are based on the megalospheric specimen with little or no mention of the character of the microspheric form. Although the designation of a megalospheric specimen as the holotype of a species is justified because this form is usually the more numerous and therefore the more typical of the species, a detailed examination and description of the microspheric form should also be made since the more complete development of the species often is to be found only in this form. In the two genera under discussion it is impossible to determine accurately whether the initial chambers are biserial or triserial if the microspheric form is undescribed or unknown.

During recent years very little use has been made of thin-sectioning as applied to the study of the smaller Foraminifera, though this method has been used in the past by some European workers. The results of this study show that *Siphogenerinoides* and *Siphogenerina* can only be separated by apertural characteristics. In the past, however, these genera were thought to be separable only on the basis of internal structural characteristics. Only through the preparation of thin sections and acid-treated specimens can these characters be established accurately. It is important to point out here that while longitudinal thin sections are very valuable in establishing such structural details as internal siphons and the degree of overlapping in chambers of the smaller Foraminifera, they are seldom of any value in determining the triseriality of such forms as *Siphogenerina* and *Siphogenerinoides*. Only transverse thin sections cutting the initial chambers of the test can conclusively prove the triseriality or biseriality of these genera. Treating the initial chambers of these forms with dilute acid is an equally reliable method of determining whether they are triserial or biserial and is much faster than thin-sectioning. For this paper thin sections and acid-treated specimens have been prepared and figured of the following described species of *Siphogenerinoides: Siphogenerinoides plummeri* (Cushman) 1926, *S. bramletti* Cushman 1929, *S. cretacea* Cushman 1929, *S. parva* Cushman 1929, *S. brevispinosa* Cushman 1939, *S. whitei* Church 1941. *S. clarki* Cushman and Campbell 1936 and *S. clarki costifera* Cushman and Goudkoff 1944 have been examined since the preparation of this paper and are not figured. The structural and apertural characteristics of these forms are the same as those found to be typical of *Siphogenerinoides* in this study.

Siphogenerinoides eleganta (Plummer) is not figured in this paper. It is very similar to *S. brevispinosa* Cushman. These two species are usually small and are structurally similar to the larger species of *Siphogenerinoides*. The aperture of each of these forms resembles the aperture of larger members of the genus in only a general manner, and it is thought that these species may constitute a new subgenus of *Siphogenerinoides*. *Siphogenerinoides eleganta* (Plummer), *S. brevispinosa* Cushman, and other similar forms will be dealt with in a future paper.

No specimens of *Siphogenerinoides ewaldi* (Karsten) 1858, *S. parva* Cushman, var. 1941, and *S. plummeri coya* Frizzell 1943 have been available for study.

The following species are new: *Siphogenerinoides bermúdezi*, *S. bermúdezi peruviana*, *S. landesi*, *S. reticulata*, and *S. revoluta*. An effort has been made to prepare sufficient views of the exterior of the new species to establish accurately their true characteristics and the range of variation within the species. Too often species referred to *Siphogenerina* and *Siphogenerinoides* are illustrated by side views only, no view of the aperture being given. Since the generic position of many forms of the Foraminifera is often based to a large extent on their apertural characteristics, such an omission is very undesirable when dealing with these two similar forms.

Disposition of type specimens.—The specimens illustrated in this paper have been deposited in the type collections of the United States National Museum, Washington, D. C. Topotypes of the new species described have been deposited in the collections of the Cushman Laboratory for Foraminiferal Research, Sharon, Massachusetts; The American Museum of Natural History, New York City; and The University of Texas, Austin, Texas. The localities where they were collected are shown in figure 1.

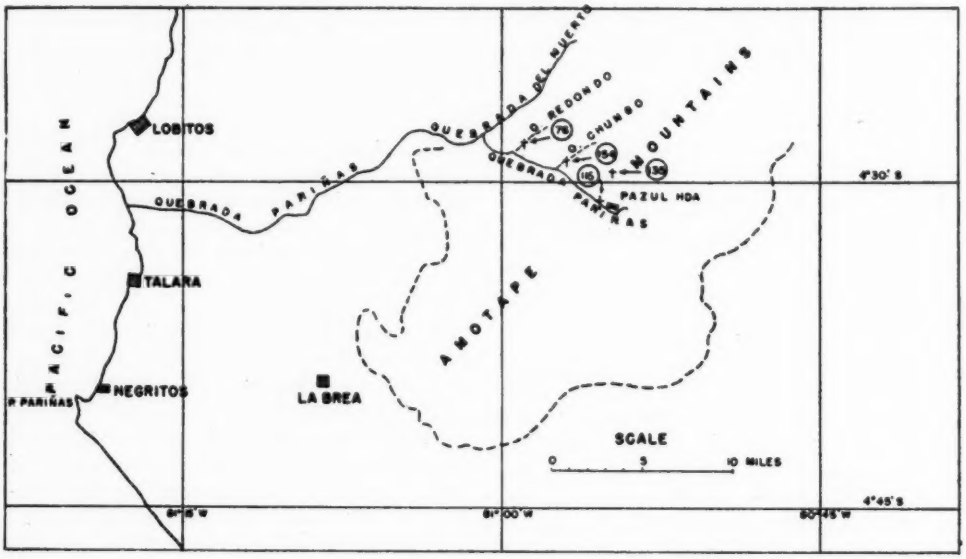


FIG. 1—Map of part of northwestern Peru showing sample localities. The stream in the Amotape Mountains labeled Quebrada Pariñas is really Quebrada Pazul.

Acknowledgements.—The preparation of this paper has been made possible largely through the cooperation of Dr. J. A. Cushman, who checked the determinations of the described species and generously supplied paratype specimens of others that would have otherwise been impossible to examine and section. Helen Jeanne Plummer (Mrs. F. B. Plummer) sent topotype specimens of the genotype and made many valuable sug-

gestions on the problems encountered in the preparation of the paper. Dr. D. L. Frizzell kindly checked the manuscript and made numerous useful suggestions. Thanks are also due Mr. J. M. Dorreen and Dr. Brooks F. Ellis.

Permission to publish the paper in its present form has been granted by the Chief Geologist and the Directors of the International Petroleum Company Limited.

The illustrations of Foraminifera were drawn by Señor Ramon Neira of Negritos, Peru, S. A.

SYSTEMATIC RELATIONSHIPS

The genus *Siphogenerina* was proposed by Schlumberger in 1882 (not 1883 as Cushman, 1940 says). It was proposed as a genus without species (according to Ellis and Messina). According to accepted principles in the case of a genus without species, the first specific name used with the generic name is taken as the type. It is assumed that *Siphogenerina costata* Schlumberger 1883 is the first name used in combination.

A free translation of Schlumberger's original description of *Siphogenerina*, as found in the Catalogue of Foraminifera, reads as follows:

> Close to *Bigenerina* but differs in having a siphon which unites the suture planes of the upper chambers.

Cushman (1926) revised the genus and described it as follows:

> Test elongate, composed at least in the microspheric form of a series of chambers arranged trior biserially, followed by a later uniserial development; walls hyaline and perforate; aperture in the uniserial portion central and terminal, usually with an elongate neck and flaring lip; interior of the chamber with a tubular connection running from the base of the apertural neck to the lip of the aperture below; wall smooth or ornamented by costae, pits, etc.

Siphogenerina is currently (Cushman 1940) described as:

> Test elongate, cylindrical, early stages typically triserial, rounded in section, later uniserial; wall calcareous, perforate; aperture in the adult terminal, with a distinct neck, phialine lip, and internal tube.

The genus *Siphogenerinoides* was proposed by Cushman in 1927 and since that time has been widely used as an index genus for sediments of Upper Cretaceous age. The original description of this genus (Cushman, 1927) is as follows:

> Test in the early stages biserial, later uniserial, aperture with a neck and phialine lip; without siphons between the chambers.

Siphogenerina plummeri Cushman was designated as the genotype, but no reference is made as to whether the biserial initial chambers are present in the microspheric or megalospheric form. Later (Cushman, 1929), the description of the genus was emended to:

> Test elongate, slightly tapering, the early stages at least in the microspheric form biserial or irregularly triserial, the later stages uniserial; wall calcareous perforate, usually with longitudinal costae; aperture typically with a neck and phialine lip but usually without siphons between the chambers.

Currently (Cushman, 1940) it is described as:

> Test elongate slightly tapering, early stages biserial, later uniserial; wall calcareous, perforate, usually with longitudinal costae; aperture with a neck and phialine lip.

Plummer (1931) conclusively established the presence of an internal siphon in the genotype *Siphogenerinoides plummeri* (Cushman). A siphon is also figured and mentioned by Cushman and Campbell (1936) in their description of *S. clarki*.

MORPHOLOGY OF SIPHOGENERINA

The structural details discussed below are based on the examination of a number of species of *Siphogenerina*. *Siphogenerina lamellata* Cushman has been selected as representative of the genus.

Aperture.—The apertural characteristics of species of *Siphogenerina* are of particular interest. These are usually described very poorly, and in many descriptions are completely ignored. Generally, reference is made to the neck and phialine lip so typical of species placed in this genus. A cursory examination of figures of various species of *Siphogenerina* will show that most of these species are illustrated by side views only.

In most species the aperture is circular with an elongate neck and phialine lip (fig. 2a). Both the neck and phialine lip are generally well developed. Exceptions are found in *Siphogenerina advena ornata* Palmer and Bermúdez and *Siphogenerina striatula*

Cushman, both of which have ovate or ellipitcal apertures. Such examples, however, are rare. Slightly below the lip of the aperture, and completely encircled by this lip, is a small circular opening, which is the uppermost end of the internal siphon present in all species I have seen of this genus (figs. 2b and 2c). The siphon reaches well up into the apertural neck and is loosely attached to one side of it. At least 30 per cent of the well-preserved specimens examined have this distinctive apertural expression of the internal siphon preserved intact, yet practically no described species of the genus has this important detail figured or described. A similar aperture is found in species of *Uvigerina*, which also belongs to the Buliminidae.

Siphon.—The internal siphon of *Siphogenerina* is typically circular in transverse section. This structure extends from the initial chambers upward through the foramina of the intermediate chambers to the aperture of the last-formed chamber of the test. In no specimen examined does the siphon completely fill the neck of the aperture. The siphon does not follow a straight line through the chambers but twists in a mild corkscrewlike manner, being attached, for example, to the right-hand side of the foramen of one chamber, the far side of the foramen of the next higher chamber, and the left-hand side of the foramen of the next superjacent chamber. The siphon then twists through approximately 90° from the foramen of one chamber to that of the next superjacent or subjacent chamber. The twisting character of the siphon indicates a spiral ancestry for this genus. Similarly twisting siphons are also found in other genera such as *Bulimina*, *Virgulina* and *Uvigerina*—all in the Buliminidae.

Chamber arrangement.—The triserial initial portion of the microspheric form is very short. The chamber arrangement following the triserial initial stage may be biserial and later uniserial or may become immediately uniserial. Specimens becoming immediately uniserial following the triserial initial chambers usually have indications of a tendency to become biserial first. This is evinced by the irregular arrangement of the first few uniserial chambers following the triserial stage of development. In the megalospheric form the test begins with a large rounded proloculum followed by a short biserial stage and then becomes uniserial. The biserial stage may be skipped, and the test becomes immediately uniserial, in which event the first few uniserial chambers are irregularly arranged.

Sutures.—The sutures of the uniserial chambers are often straight and transverse to the long axis of the test. On costate species, however, the sutures are usually retroflexed. The form of the chambers and their sutures can be most clearly and accurately determined by means of thin-sections. In species having retroflexed sutures the greatest development of overlapping is along the costae if such structures are present. It is not necessary, however, that costae be present for the development of retroflexed sutures. *S. dimorpha pacifica* Cushman, a Recent form, has no indication of costae yet has well-developed retroflexed sutures. Apparently there is some correlation between these two structural features, and it is suggested that the costae may be the result of a high development of retroflexed sutures.

MORPHOLOGY OF SIPHOGENERINOIDES

The following discussion of the structure of *Siphogenerinoides* is based on a detailed examination of thin sections and acid-treated specimens of the genotype, topotype specimens of other described species, and the four new species. In addition, several hundred other specimens, including the four new species, were examined by the same means. With the exception of *S. eleganta* (Plummer) and *S. brevispinosa* Cushman, which have modified apertures, and possibly the two previously mentioned species that were not available for examination, the following structural details were found to apply to all described species of this genus.

Aperture.—The aperture of *Siphogenerinoides* is arcuate in shape. In *S. plummeri* (Cushman) the arcuate form is unusually pronounced. Species of this genus also have a much shorter development of the apertural neck than is typical for most species of *Siphogenerina*. *S. plummeri* (Cushman) has the most highly developed apertural neck of all species of the genus and, in this respect, more closely approaches the apertural char-

acter of *Siphogenerina* than does any other species of *Siphogenerinoides*. In most species the neck is greatly reduced and the aperture has merely a thickened lip, which is sometimes poorly developed.

The aperture of some specimens of the species in this genus has what appear to be two toothlike projections on its concave side which extend slightly into the apertural opening. This structure was first noted by Cushman and Campbell (1936) in their description of *S. clarki* and has been figured by Plummer (1931) in redescribing *S. plummeri* (Cushman). These projections are not true teeth but the unfused or sometimes the broken ends of the apertural lip, which forms the uppermost unattached edge of the internal siphon (fig. 3c). The unattached, upper edge of the siphon is fragile and often broken. In most specimens, however, these projections are clearly the result of incomplete fusion.

Well-preserved specimens of *Siphogenerinoides* have two openings at the apertural end of the test, one much smaller than the other. The aperture is the larger of these two openings and is arcuate in shape, whereas the smaller opening is usually circular to slightly elongate. The smaller opening lies completely outside of the larger opening or aperture and is always tangent to its concave edge. The larger opening is formed by the neck or thickened apertural lip (fig. 3a) and is completely bounded by it. The apertural lip on the concave side of the aperture is not so thick as on the convex side. In some specimens the concave edge of the aperture (fig. 3e) is broken or incompletely fused as noted above. The smaller opening, lying to one side of the aperture and tangent to its concave edge, is the open end of the siphon. This smaller opening may at times be difficult to see because the fused lip of the concave edge of the aperture has a tendency to slightly overhang it in some specimens. The apertural neck and lip outline the true aperture, the lip of the concave edge of the aperture forming the unattached upper edge of the siphon (fig. 3c). The attached upper edge of the siphon (fig. 3d) is only rarely indicated by a slightly raised or upwarped bit of wall material, in all specimens showing appreciably less development and height than the lip on the convex or concave edge of the aperture (fig. 3b, c). Usually the attached edge of the siphon continues uninterruptedly into the wall material forming the septal face of the last-formed chamber. In no species is the

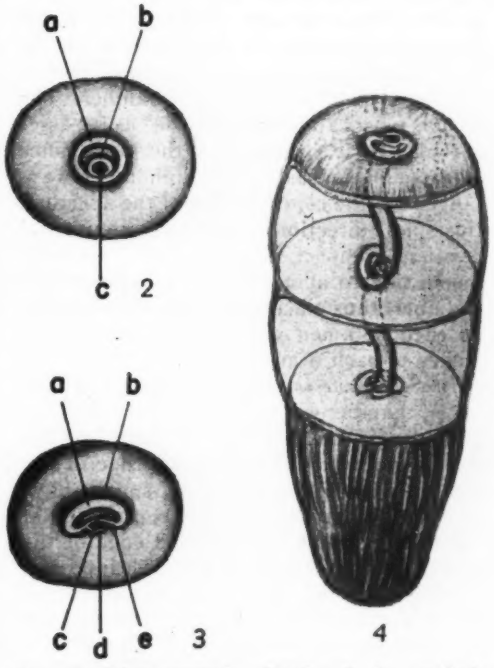


FIG. *2*—Diagrammatic sketch of the typical aperture of *Siphogenerina*. *a*, Apertural lip; *b*, unattached upper edge of internal siphon; *c*, attached upper edge of internal siphon.

3—Diagrammatic sketch of the typical aperture of *Siphogenerinoides*. *a*, Apertural lip; *b*, convex side of aperture; *c*, unattached upper edge of internal siphon; *d*, attached upper edge of internal siphon; *e*, concave side of aperture.

4—Diagrammatic sketch illustrating siphon and reorientation of the foramen of each chamber.

internal siphon enclosed by the apertural lip as is typical of *Siphogenerina*. In all species of this genus the attached upper edge of the siphon is a part of the septal face of the last-formed chamber, whereas in *Siphogenerina*, the upper edge of the siphon is a separate structure only loosely attached to the apertural neck.

Siphon.—The siphon is a prominent internal structural feature and is invariably present in all species of this genus that were

examined. The siphon, typically circular in transverse section, is sometimes slightly flattened giving it an elongate form. As in *Siphogenerina* the siphon extends from the initial chambers upward through all the chambers of the test. The siphon does not, however, pass through the foramina of the successive chambers of the test as it does in *Siphogenerina*, but forms a separate opening in the septal face of each chamber. The siphon twists approximately 90° as it passes through each chamber of the test. Since the opening formed by the siphon is always tangent to the concave edge of the aperture, this spiral direction contributes to an axial re-orientation of the arcuate aperture amounting to about 90° in each successive chamber, thus placing the axis of elongation of each foramen at approximately right angles to each other (fig. 4).

In *Siphogenerinoides* the siphon is a part of the chamber wall. This is indicated by the poor development of any thickened or lip-like structure on the attached edge of the siphon and the fact that most species have no interruption between the septal face of the chamber and the attached edge of the siphon. Where there is some such interruption, no true lip is formed, but merely a gentle upwarping of the septal face near the attached edge of the siphon.

Sutures.—The character of the sutures and overlapping chambers is generally the same as in *Siphogenerina*. A number of species of *Siphogenerinoides* have little external indication of overlapping chambers, though in most species the sutures are retroflexed. Species having retroflexed sutures have this character developed most in the last-formed chambers of the test and along the longitudinal costae when costae are present. For example, in *S. bermúdezi*, n. sp., the sutures of the early uniserial chambers are only slightly irregular, but the sutures of the last two or three chambers of the adult test are markedly retroflexed. In *S. landesi*, n. sp., the coarse, highly developed longitudinal costae tend to disappear toward the apertural end of the test and are replaced by very exaggerated retroflexed sutures depressed strongly at the base of each overlapping chamber. In the other two new species there is an unusually high development of retroflexed sutures. *S. reticulata*, n. sp., has sutures that are raised and thickened and so strongly retroflexed and fused together as to give the exterior of the test a gridlike appearance. A similar condition is found in *S. revoluta*, n. sp., but here the sutures are depressed and not thickened as in the former species. The above are unusual examples but other species have these characters developed to a minor degree.

Chamber arrangement.—Even through the use of transverse thin sections it is often difficult to determine whether the initial chambers of this genus are biserial or triserial. This is particularly true when the species being examined is small, as are many of the described species, especially at the initial end of the test. Longitudinal thin sections, as pointed out earlier, are of little value for such a determination. A more rapid and expedient method is that described by Plummer (1931) in which dilute acid is applied to the test to dissolve the chamber walls. This method was employed on microspheric specimens of *S. plummeri* (Cushman). After treatment with acid the initial triserial chambers exhibit an irregular configuration. Available microspheric specimens of other described species of the genus were treated in a similar manner and in each the initial chambers were found to be triserial. The new species described in this paper are likewise triserial.

FAMILY RELATIONSHIPS

Plummer (1931) placed *Siphogenerinoides* in the foraminiferal family Buliminidae Cushman. *Bulimina*, *Uvigerina* and *Siphogenerina*, as well as other genera of this family have similarly twisting siphons and triserial initial chambers. The absence of any indication of coiling, the triserial initial chambers, and the twisting internal siphon all signify that *Siphogenerinoides* should be placed in the Buliminidae, a family in which these structural features are fundamental characters.

CONCLUSIONS

Earlier descriptions of the genus *Siphogenerinoides* have been inadequate and have led some workers to consider it a synonym of *Siphogenerina*. The results of this study prove that the structural characteristics by which *Siphogenerinoides* was formerly con-

sidered to differ from *Siphogenerina* are identical with those of the latter genus. These two genera are differentiated, however, by the circular aperture enclosing the siphon, in *Siphogenerina*, as opposed to the reniform or arcuate aperture of *Siphogenerinoides*, which does not enclose the siphonal orifice.

Because of the twisting internal siphon, lack of coiling and the triserial initial chambers, the genus *Siphogenerinoides* is here placed in the foraminiferal family Buliminidae Cushman.

Siphogenerinoides eleganta (Plummer) and *S. brevispinosa* Cushman are usually small and have a modified form of *Siphogenerinoides* aperture. These species probably constitute a new subgenus of *Siphogenerinoides*.

With the exception of *S. eleganta* (Plummer) and *S. brevispinosa* Cushman, which range as high as upper Eocene, *Siphogenerinoides* is restricted to sediments of Upper Cretaceous age.

SYSTEMATIC DESCRIPTIONS

Family BULIMINIDAE

Subfamily UVIGERININAE

Genus SIPHOGENERINA Schlumberger, 1882

SIPHOGENERINA LAMELLATA Cushman

Plate 71, figures 1a, b

Siphogenerina lamellata CUSHMAN, 1918, U.S. Geol. Survey Bull 676, p. 55, pl. 12, figs. 3a, b.

Test elongate, tapering, initial end of the megalospheric form rounded, initial end of microspheric form bluntly pointed, initial chambers of microspheric form triserial; wall calcareous, perforate; surface ornamentation consisting of six to eight equidistant, coarse, flangelike longitudinal costae continuous over the sutures, reaching from part way up the last-formed chamber to the initial end of the test, where they fuse, costae of moderate height at the apertural end and increasing in height toward the initial end of the test, with slightly finer raised minor costae lying between the major costae and reaching from the last-formed chamber one-third to two-thirds of the length of the test; chambers comparatively few, slightly inflated; sutures distinct, retroflexed along both major and minor costae; internal siphon connecting the initial chambers with the later chambers, siphon twisting approximately 90° per chamber as it passes through each chamber, siphon passing through the foramen of each chamber and loosely attached to the inside edge of each foramen; aperture central, terminal, circular, with a neck and phialine lip, uppermost end of internal siphon clearly visible as a small circular opening lying inside of the apertural opening.

Dimensions of hypotype (USNM 103962), from Bravo well no. 2, 96 feet depth, Trujillo Prov., Dominican Republic: Length 1.34 mm.; breadth 0.56 mm.

Genus SIPHOGENERINOIDES Cushman, 1927

Siphogenerinoides CUSHMAN, 1927, Cushman Lab. Foram. Research, Contr., vol. 3, p. 63.

Genotype, *Siphogenerina plummeri* Cushman.

Test elongate, slightly tapering, initial chambers of the microspheric form triserial followed either by a series of biserial chambers or a short series of irregularly arranged uniserial chambers and then symmetrically uniserial, megolospheric form with a large rounded proloculum followed by either biserial chambers or irregularly arranged uniserial chambers and then symmetrically uniserial; chambers numerous, inflated in some species, usually with costae; sutures usually retroflexed, especially along the continuous costae; internal siphon connecting the initial chambers with the last-formed chamber, siphon twisting approximately 90° per chamber and forming a separate opening in the septal face of each chamber; aperture central, terminal, arcuate or reniform with a lip and short neck, a small circular opening, which is the apertural expression of the internal siphon, lies outside the aperture and is tangent to its concave edge.

SIPHOGENERINOIDES PLUMMERI (Cushman)

Plate 71, figures 2a, b, 3, 26

Siphogenerina plummeri CUSHMAN, 1926, U. S. Nat. Mus. Proc., vol. 67, art. 25, p. 18.

Siphogenerina plummeri Cushman. CUSHMAN, 1926, Cushman Lab. Foram. Research, Contr., vol. 2, p. 15, pl. 1, fig. 7.

Siphogenerinoides plummeri (Cushman). CUSHMAN 1927, *idem*, vol. 3, p. 63, pl. 13, fig. 16

Siphogenerinoides plummeri (Cushman). CUSH-

MAN, 1928, Cushman Lab. Foram. Research Spec. Pub. no. 1, pl. 33, fig. 27, pl. 34, fig. 16.
Siphogenerinoides plummeri (Cushman). CUSHMAN, 1929, Cushman Lab. Foram. Research, Contr. vol. 5, p. 55.
Siphogenerinoides plummeri (Cushman). PLUMMER, 1931, Texas Univ. Bull. 3101, p. 183, pl. 9, figs. 1–6.

Test elongate, cylindrical, slowly increasing in diameter toward the apertural end, about five times as long as broad, initial end bluntly rounded in the megalospheric form and slightly spinose in some specimens, very attenuate in the microspheric form, most microspheric specimens with flattened, twisted, biserial stage, others with more symmetrically rounded pointed initial chambers; earliest chambers triserial in the microspheric form then biserial and later uniserial, megalospheric form with a large rounded proloculum followed by several biserial chambers and then uniserial; wall hyaline, conspicuously perforate and ornamented by eight to thirteen sharp longitudinal costae, which may be continuous over the sutures or may be broken into small downward-projecting, short, sharp spines, and also by less distinct minor costae, uppermost portion of the major costae usually broken over the sutures; sutures retroflexed along the major costae, depressed slightly in the early chambers and increasingly depressed toward the apertural end of the test; internal siphon reaching from the initial chambers to the last-formed chamber, siphon twisting through about 90° per chamber as it passes through the test, uppermost end of siphon forming a small separate opening located outside and tangent to the concave side of the aperture, unattached upper edge of the siphon formed by the apertural lip on the concave side of the aperture, which may be broken or incompletely fused, other edge of siphon continuous with the septal face of the last-formed chamber, which is slightly upwarped near the attached edge of the siphon; aperture central, terminal, sharply arcuate, on a short neck with a flaring phialine lip, concave side of apertural lip usually broken or incompletely fused with the two ends of the apertural lip elevated above the level of the aperture and somewhat resembling teeth.

Dimensions of topotype (USNM 103974), from Plummer Station 694, uppermost Navarro formation (Upper Cretaceous), Walker Creek north of Cameron, Milam County, Texas: length 1.12 mm.; breadth 0.28 mm.

SIPHOGENERINOIDES EWALDI (Karsten)

Orthocerina ewaldi KARSTEN, 1858, Versam. deutsch. Nat. Aerzte, Amtlicher Ber. 32, p. 114, pl. 6, figs. 3a–c.
Orthocerina ewaldi Karsten. KARSTEN, 1886, Geol. ancienne Colombie, Bolivarienne, Venezuela, Nouvelle Grenada et Ecuador, p. 62, pl. 6, figs. 3a–c.
Siphogenerinoides ewaldi (Karsten). CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, p. 58.
Siphogenerinoides ewaldi (Karsten). CUSHMAN 1930, *idem*, vol. 6, p. 68, pl. 9, figs. 10–12.

No specimens of this form have been available for study. It is incompletely known, usually being represented by molds from which wax impressions have been made. The resultant impressions seem typical of *Siphogenerinoides* but no apertural views have been figured nor is it likely that such details would be sufficiently well preserved for an accurate determination. Karsten, in his original paper, gives several figures of this species, one of which is a thin section showing an internal siphon. Since *Siphogenerina* is not known from the Upper Cretaceous and Karsten figures a siphon in his specimen, it seems likely that this species may belong to *Siphogenerinoides*.

SIPHOGENERINOIDES BRAMLETTI Cushman
Plate 71, figures 8–10

Siphogenerinoides bramletti CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, p. 56, pl. 9, figs. 5–6.

Test elongate, slightly tapering, about four times as long as broad, greatest width at the apertural end; initial chambers of the microspheric form triserial followed by a short series of biserial chambers and then uniserial, megalospheric form with a large rounded proloculum, followed by a short series of biserial chambers and then uniserial; sutures of the uniserial chambers distinct and slightly retroflexed along the eight to ten longitudinal costae, which are continuous over the sutures and extend from the initial end of the test to the base of the last-formed chamber, which is smooth and free of ornamentation; wall calcareous, perforate; with clearly defined internal siphon connecting the initial chambers with the

last-formed chamber of the test, siphon twisting approximately 90° per chamber and forming a small separate opening lying outside and tangent to the concave edge of the aperture, opening often partially obscured by the apertural lip; aperture central, terminal, arcuate, without neck but with thickened lip, usually completely fused on the concave side of the aperture, with small opening lying outside and tangent to concave edge of the aperture.

Dimensions of paratype (USNM 103968), from the Cushman collection of the Upper Cretaceous Colon Shale, Venezuela, S. A.: length 0.80 mm.; breadth 0.20 mm.

The figured exterior view and the thin section are of paratypes kindly supplied by Dr. J. A. Cushman. The exterior view is of a broken specimen which is somewhat stubbier than typical for the species. The general shape of the test varies, with some specimens having their greatest diameter near the central portion of the test. Specimens from Peru are typical. The figure showing the triserial initial chambers is a hypotype (USNM 103967), from the Upper Cretaceous "*Clavulina* shale," sample 76-L, Square Mile 14–N–25, one-half mile north of Redonda, Department of Piura, northwestern Peru.

SIPHOGENERINOIDES PARVA Cushman
Plate 71, figures 11, 12

Siphogenerinoides parva CUSHMAN, 1929, Cushman Lab. Foram. Research Contr. vol. 5, p. 58, pl. 9, figs. 11–13.
Siphogenerinoides parva Cushman. CUSHMAN, 1941, *idem*, vol. 17, p. 93, pl. 22, fig. 25.

Test elongate, slightly tapering, greatest width toward the apertural end, about three times as long as broad, megalospheric form with a large rounded proloculum followed by a short series of biserial chambers and then uniserial; sutures distinct, depressed, slightly irregular; wall calcareous, perforate, ornamented by numerous low, longitudinal costae, which are discontinuous over the sutures and usually missing from the last-formed chamber; with distinct internal siphon connecting the early chambers with the last-formed chamber, siphon twisting through some 90° per chamber as it passes through the test, uppermost end of siphon forming a small opening lying outside and tangent to the concave edge of the aperture; aperture central, terminal, arcuate, with a very slight neck and thickened lip, apertural lip often incompletely fused on the concave side of the aperture, with small opening lying outside and tangent to the concave edge of the aperture.

Dimensions of paratype (USNM 103975), from the Cushman collection of the Upper Cretaceous Colon Shale, Venezuela: length 0.63 mm.; breadth 0.21 mm.

The figured exterior views and the thin section are of a single megalospheric specimen supplied by Dr. J. A. Cushman. The specimen is broken but the foramen is typically that of *Siphogenerinoides*. No microspheric specimens have been available for determining the triseriality of this species.

SIPHOGENERINOIDES CRETACEA Cushman
Plate 71, figures 13–16

Siphogenerinoides cretacea CUSHMAN, 1929, Cushman Lab. Foram. Research Contr. vol. 5, p. 58, pl. 9, figs. 14, 15.
Siphogenerinoides cretacea Cushman. CUSHMAN, 1941, *idem*, vol. 17, p. 93, pl. 22, figs. 20–23.
Siphogenerinoides cretacea Cushman. FRIZZELL, 1943, Jour. Paleontology, vol. 17, no. 4, p. 349, pl. 56, fig. 28.

Test elongate, tapering, about four times as long as broad, initial end of microspheric form slightly pointed, megalospheric form with sides nearly parallel and initial end rounded, greatest width near the apertural end, initial chambers of the microspheric form triserial followed by a series of biserial chambers and then uniserial, megalospheric form with a large rounded proloculum followed by a very short series of biserial chambers and then uniserial; chambers distinct, only slightly inflated, overlapping in a slightly irregular manner particularly toward the apertural end of the test; sutures distinct in the later chambers of the test but obscure in the early portion, slightly depressed, more so toward the apertural end, slightly retroflexed particularly in the last few chambers; wall calcareous, perforate, ornamented by numerous fine longitudinal costae, which may be continuous or broken over the sutures, costae never cover the last-formed chamber; internal siphon extending from the initial chambers to the last-formed chamber, siphon twisting through approximately 90° per chamber,

uppermost end of siphon forming a small separate opening lying outside and tangent to the concave edge of the aperture, unattached upper edge of siphon formed by apertural lip of the concave edge of the aperture, other edge of siphon continuous with the septal face, at about the same height as the septal face and lower than the unattached edge of siphon; aperture central, terminal, arcuate, on a short neck bounded by a slightly thickened lip, concave side of apertural lip usually broken or incompletely fused leaving two inward-projecting toothlike structures, small opening lying outside aperture and tangent to its concave edge.

Hypotype (USNM 103971), from the Upper Cretaceous "*Clavulina* shale," sample 154-A in Quebrada Chungo, Square Mile 14–N–27, 2 miles east of Redonda, Department of Piura, northwestern Peru. Dimensions: length 1.30 mm.; breadth 0.50 mm.

The ornamentation of this species varies considerably. In some specimens the costae are very fine and restricted to the earlier chambers, while other specimens have coarser costae, some of which may persist to the base of the last-formed chamber. The apertural lip, when completely fused on the concave side of the aperture, often overhangs the opening formed by the uppermost end of the siphon partially obscuring it. The specimen from the "*Clavulina* shale" which Frizzell (1943) figures is closer to *S. bermudezi* n. sp.

SIPHOGENERINOIDES CLARKI
Cushman and Campbell

Siphogenerinoides clarki CUSHMAN AND CAMPBELL, 1936, Cushman Lab. Foram. Research Contr., vol. 12, p. 91, pl. 13, figs. 9–12.
Siphogenerinoides clarki Cushman and Campbell. FRIZZELL, 1943, Jour. Paleontology, vol. 17, no. 4, p. 349, pl. 56, fig. 30.

Test elongate, slightly tapering, circular in transverse section, greatest breadth near the apertural end, early stages triserial in the microspheric form, biserial or uniserial in the megalospheric, uniserial in the adult; chambers fairly distinct, but very slightly inflated, somewhat overlapping, increasing gradually in height as added; sutures fairly distinct, very slightly if at all depressed; wall fairly thick, conspicuously perforate, smooth, with faint traces of longitudinal striations; aperture terminal, with a distinct lip, with one side convex, the other concave, occasionally ending in two inwardly projecting toothlike prominences. Length 1.20–1.30 mm.; diameter 0.35–0.40 mm.

Holotype (Cushman Coll. No. 23554) from the uppermost Cretaceous, in black shale exposed along creek in pasture, in company with *Baculites* sp. and *Nemadon* sp., ½ mile northeast from ranch house of Dr. Marsh, Marsh Creek, Mt. Diablo Quadrangle, California, collected by Bruce L. Clark and A. S. Campbell.

The species differs from *S. plummeri* in the smooth surface and more cylindrical form.

This species is an interesting one, particularly in the apertural characters which are shown in our plate, which parallel those shown in *S. plummeri* (Cushman), as figured by Mrs. Plummer (Univ. Texas Bull. 3101, 1931, p. 183, pl. 9, figs. 1–6).

Our specimens show a definite internal tube connecting the apertures.—CUSHMAN AND CAMPBELL, 1936.

No specimens of this species have been available for sectioning. An examination of topotypes subsequent to the preparation of this paper shows that this form has the typical *Siphogenerinoides* aperture described above. The internal siphon, however, does not connect the apertures but forms a separate opening tangent to the concave edge of the aperture.

SIPHOGENERINOIDES BREVISPINOSA
Cushman
Plate 71, figures 5–7, 27

Siphogenerinoides brevispinosa CUSHMAN, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 92, pl. 16, figs. 7a–b.

Test elongate, early portion pointed, slightly tapering, three to four times as long as broad, sometimes slightly compressed; initial chambers of the microspheric form triserial followed by either a few biserial chambers or irregularly arranged uniserial chambers and then uniserial, chambers indistinct in the early part of the test but distinct in the later part, slightly inflated; sutures distinct in the later portion of the test but obscure in the early portion; wall calcareous, conspicuously perforate with short coarse spines covering the entire surface of the test; with distinct internal siphon connecting the initial chambers with the last-formed chamber, siphon twisting approximately 90° per chamber; aperture broadly arcuate, central, terminal, with thickened lip on convex side, concave side of aperture smooth, without lip but with a

slight upwarping of wall material near the attached edge of the siphon.

Dimensions of paratype (USNM 103970), from Cushman collection: length 0.40 mm.; diameter 0.14 mm.

The figures, with the exception of figures 5a–b which are after Cushman, are of paratype specimens supplied by Dr. J. A. Cushman. The specimen showing triseriality (USNM 103969, fig. 27) was supplied by Mrs. Plummer. The specimens supplied by Dr. Cushman are somewhat smaller and stubbier than the specimen figured by him.

The short, stubby spines covering the entire test make the sutures of the earlier chambers very indistinct. Thin sections show the internal siphon and acid-treated specimens show the form to be triserial in the initial chambers of the microspheric form. The aperture of this form has an unusually poor degree of fusion of the lip on the concave side, the apertural lip forming the open edges of the siphon.

This species has been recorded from sediments of questionable Upper Cretaceous or Paleocene age. Similar forms of generally small size such as *S. eleganta* (Plummer), and others, are known to occur as high as upper Eocene in the United States. The aperture of such forms is a very generalized version of that typical of true *Siphogenerinoides*. At present these forms are tentatively considered a possible subgenus of *Siphogenerinoides*. These forms will be dealt with in a later paper.

SIPHOGENERINOIDES WHITEI Church
Plate 72, figures 8–12

Siphogenerinoides whitei CHURCH, 1941, California, Div. Mines Bull. 118, pt. 2, p. 182, pl. 67, fig. 37.

Siphogenerinoides whitei Church. SCHENCK, 1943, Jour. Paleontology, vol. 17, no. 1, p. 62.

Test elongate, slightly tapering, greatest diameter near the apertural end, initial end of microspheric form gently pointed, in megalospheric form broadly rounded; initial chambers of microspheric form distinctly triserial, then biserial or irregularly uniserial followed by uniserial chambers, which compose the major portion of the test, megalospheric form with a large rounded proloculum followed by a short series of irregularly arranged uniserial chambers and then symmetrically uniserial; chambers indistinct except for the last-formed chamber, which is somewhat inflated, last-formed chamber smooth, broadly rounded, without ornamentation and somewhat overlapping the subjacent chamber; wall calcareous, perforate, highly ornamented by numerous well-developed highly irregular short costae, which are both continuous and discontinuous over the sutures; sutures irregular and retroflexed, slightly depressed, and almost completely obscured by the surface ornamentation except at the last-formed chamber; internal siphon connecting the initial chambers with the last-formed chamber, siphon twisting about 90° per chamber and forming a small separate opening lying outside the aperture and tangent to its concave edge, unattached upper edge of siphon formed by the lip of the concave edge of the aperture, other edge of siphon continuous with the septal face of the last-formed chamber and at the same height, siphon without lip or any upwarping of the septal face on the attached side; aperture central, terminal, arcuate, without neck but bounded by a slightly thickened lip, which is usually completely fused on the concave side of the aperture, with small opening lying outside and tangent to the concave edge of the aperture.

Dimensions of hypotype (USNM 103980): length 1.82 mm.; diameter 0.77 mm. Hypotype specimens from the Upper Cretaceous "*Clavulina* shale," sample 135-A, Square Mile 13–N–29, 2 miles north of Pazul, Department of Piura, northwestern Peru.

Topotype specimens with which the hypotypes have been compared have the last two chambers free of ornamentation. Peruvian specimens have only the last chamber smooth. The costae are usually fused together and more regular toward the base of the test. The concave edge of the aperture in this species is generally completely fused and unbroken. This makes the separation of the opening formed by the siphon and that of the aperture very pronounced.

SIPHOGENERINOIDES PARVA Cushman, var.

Siphogenerinoides parva Cushman, var., 1941, Cushman Lab. Foram. Research Contr., vol. 17, p. 94, pl. 22, fig. 24.

Variety differing from the typical in the orna-

mentation which consists of numerous, very fine, longitudinal costae, usually more or less continuous across the sutures. This occurs in the *S. bramlettei* zone of the Colon shale. The figured specimen is from the State of Tachira, Venezuela. —CUSHMAN, 1941.

No specimens of this species have been available for examination.

SIPHOGENERINOIDES PLUMMERI COYA Frizzell

Siphogenerinoides plummeri coya Frizzell, 1943, Jour. Paleontology, vol. 17, no. 4, p. 349, pl. 56, fig. 29.

Test small, elongate, four to four and one-half times as long as wide, slightly tapering to last chamber, early chambers biserial, later chambers uniserial, circular in cross section; chambers somewhat indistinct, very slightly inflated; sutures indistinct, very slightly depressed; surface ornamented by about eight longitudinal costae, sharp, transversing sutures without change, ending abruptly at a raised thread surrounding septal face; aperture broadly elliptical, with a very short neck.

Dimensions of holotype, from I.P. Co. well 3040, 1945 feet depth: height 0.73 mm.; diameter 0.22 mm.—FRIZZELL, 1943.

No specimens of this variety have been available for study. The figure and description indicate that the holotype is probably a broken specimen. No apertural view is given, but the description suggests that this form may belong to *Siphogenerinoides*.

SIPHOGENERINOIDES CLARKI COSTIFERA Cushman and Goudkoff

Siphogenerinoides clarki costifera CUSHMAN AND GOUDKOFF, 1944, Cushman Lab. Foram. Research Contr., vol. 20, p. 58, pl. 9, fig. 19.

EXPLANATION OF PLATE 71

FIG. *1*—*Siphogenerina lamellata* Cushman. Hypotype (USNM 103962), ×40. *a*, Side view of megalospheric specimen; *b*, apertural view showing open end of siphon encircled by the apertural opening. (p. 469)

2–4, 26—*Siphogenerinoides plummeri* (Cushman). Topotypes (USNM 103974). *2, 3*, ×40: *4*, ×60; *26*, ×150. *2a*, Side view of megalospheric specimen; *2b*, apertural view showing separate opening formed by uppermost end of siphon, apertural lip incompletely fused on concave side of aperture. *3*, Microspheric specimen with symmetrically rounded initial end. *4*, Thin section of megalospheric specimen showing gently twisting siphon. *26*, Initial chambers of acid-treated microspheric specimen showing irregular triserial chamber arrangement. (p. 469)

5—*Siphogenerinoides brevispinosa* Cushman. ×102. (After Cushman). *a*, Side view; *b*, apertural view showing incomplete fusion on straight side of aperture. (p. 469)

6, 7, 27—*Siphogenerinoides brevispinosa* Cushman. *6*, ×110; *7*, ×150; *27*, ×200. *6*, Paratype specimen (USNM 103970) side view. *7*, Thin section of paratype showing internal siphon. *27*, Initial chambers of acid-treated microspheric specimen (USNM 103969) showing triserial initial chambers. (p. 472)

8–10—*Siphogenerinoides bramletti* Cushman. *8, 10*, Paratypes (USNM 103968). ×80; *9*, hypotype, ×80. *8a*, Side view of broken specimen; *8b*, apertural view showing separate opening formed by the siphon. *9*, Initial chambers of acid-treated microspheric specimen (USNM 103967) showing triserial arrangement. *10*, Thin section showing internal siphon. (p. 470)

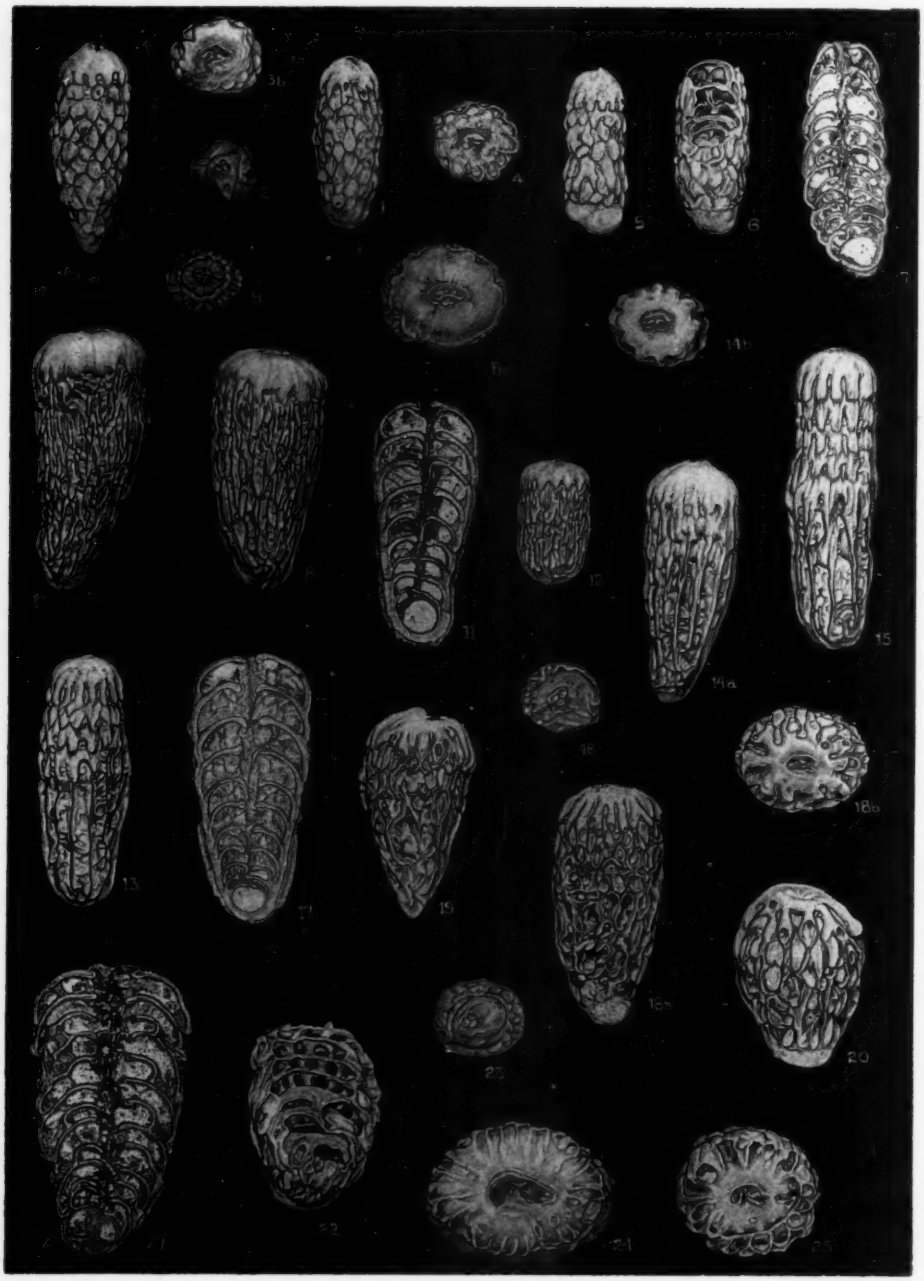
11, 12—*Siphogenerinoides parva* Cushman. Paratype (USNM 103975). *11a*, Side view of megalospheric specimen; *11b*, apertural view, ×80. *12*, Thin section of same specimen showing internal siphon, ×100. (p. 471)

13–16—*Siphogenerinoides cretacea* Cushman. Hypotypes (USNM 103971), ×40. *13a*, Side view of microspheric specimen; *13b*, apertural view showing toothlike protuberances formed by incompletely fused apertural lip. *14, 15*, Side views of megalospheric specimens showing variation in ornamentation. *16*, Thin-section of megalospheric specimen showing internal siphon. (p. 471)

17–19—*Siphogenerinoides bermúdezi peruviana* Stone, n. var. *18*, Holotype (USNM 103965), ×40; *17, 19*, paratypes (USNM 103966), ×40. *17*, Side view of megalospheric form. *18a*, view of holotype; *18b*, apertural view showing separate opening formed by the siphon, apertural lip completely fused. *19*, Thin section of megalospheric specimen showing internal siphon. (p. 476)

20–25—*Siphogenerinoides bermúdezi* Stone, n. sp., *20*, Holotype (USNM 103963), ×40; *21–25*, paratypes (USNM 103964), ×40. *20a*, Side view of holotype; *20b*, apertural view showing separate opening formed by the siphon, apertural lip completely fused. *21a*, Side view of megalospheric paratypes; *21b*, apertural view showing separate opening formed by the siphon, apertural lip incompletely fused. *22*, Immature megalospheric form. *23*, Initial chambers of acid-treated microspheric specimen showing triserial chamber arrangement. *24*, Side view of broken microspheric specimen. *25*, Thin section showing internal siphon in microspheric specimen. (p. 475)

Stone, *Siphogenerinoides* Cushman



Stone, *Siphogenerinoides* Cushman

Variety differing from the typical in the surface of the test which, instead of being smooth, has definite, longitudinal costae.

Holotype of variety (Cushman Coll. No. 42245) from Cretaceous, 6988 ft. depth in Jergins Oil Cheney Ranch No. 1 Well, sec. 29, T. 14 S., R. 13 E., Fresno Co., California.—CUSHMAN AND GOUDKOFF, 1944.

No specimens of this form have been available for sectioning during the preparation of this paper. Topotype specimens examined in California have the typical *Siphogenerinoides* type of aperture.

SIPHOGENERINOIDES BERMÚDEZI Stone, n. sp.
Plate 71, figures 20–25

Test elongate, slightly tapering in the microspheric form, which has a sharply pointed initial end, megalospheric form rounded at the initial end, circular in transverse section, greatest diameter near the apertural end; initial chambers of the microspheric form distinctly triserial followed by approximately 12 biserial chambers and then uniserial, megalospheric form with a large rounded proloculum followed by a short series of biserial chambers and then uniserial; chambers distinct, slightly inflated, overlapping in an irregular manner; sutures generally distinct, strongly depressed, particularly toward the apertural end, retroflexed especially toward the apertural end of the test; wall conspicuously perforate with very faint minute, broken longitudinal striae generally restricted to the early portion of the test; internal siphon passing through the chambers in a gentle corkscrewlike manner twisting some 90° per chamber, siphon connecting the initial chambers with the last-formed chamber and forming a small separate opening in the septal face of each chamber, opening lies outside and tangent to the concave edge of the aperture, unattached upper edge of siphon formed by the apertural lip on the concave edge of the aperture, attached upper edge of siphon continuous with the septal face of the last-formed chamber with a slight upwarping of wall material near the edge of the siphon; aperture central, terminal, arcuate, on a short neck bounded by a thickened lip, concave side of aperture often

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EXPLANATION OF PLATE 72

FIGS. *1–7—Siphogenerinoides revoluta* Stone, n. sp. *1*, Holotype (USNM 103978), ×40; *2–7*, paratypes (USNM 103979) ×40. *1*, Side view of megalospheric holotype. *2*, Initial chambers of acid-treated microspheric specimen showing triserial initial chambers. *3a*, Side view of microspheric form; *3b*, apertural view showing separate opening formed by siphon and incompletely fused apertural lip. *4*, Transverse thin section showing highly irregular overlapping chambers and separate opening formed by siphon. *5*, Side view of immature megalospheric specimen. *6*, Side view of immature megalospheric specimen with walls broken showing internal siphon. *7*, Thin section of megalospheric specimen showing siphon. (p. 477)

8–12—Siphogenerinoides whitei Church. Hypotypes (USNM 103980), ×40. *8a*, Side view of megalospheric specimen; *8b*, apertural view showing separate opening formed by the siphon, apertural lip completely fused. *9*, Initial chambers of acid-treated microspheric specimen showing triserial chamber arrangement. *10*, Side view of microspheric form. *11*, Thin section of megalospheric specimen showing internal siphon; note separate opening formed by siphon at aperture of last-formed chamber. *12*, Side view of immature megalospheric specimen. (p. 473)

13–17—Siphogenerinoides landesi Stone, n. sp., *13*, Holotype (USNM 103972), ×40; *14–17*, paratypes (USNM 103973), ×40. *13*, Side view of holotype. *14a*, Side view of microspheric specimen; *14b*, apertural view showing separate opening formed by siphon. *15*, Side view of larger megalospheric specimen. *16*, Initial chambers of acid-treated microspheric form showing triserial chamber arrangement. *17*, Thin section showing internal siphon. (p. 476)

18–25—Siphogenerinoides reticulata Stone, n. sp. *18*, Holotype (USNM 103976) ×40; *19–25*, paratypes (USNM 103977), ×40. *18a*, Side view of holotype; *18b*, apertural view showing separate opening formed by siphon, apertural lip incompletely fused. *19*, Side view of microspheric specimen. *20*, Side view of immature specimen. *21*, Thin section of megalospheric specimen showing siphon. *22*, Side view of megalospheric specimen showing approximately 90° twist in the broken remnant of siphon. *23*, Initial chambers of acid-treated microspheric specimen showing triserial chamber arrangement. *24*, Apertural view of broken specimen showing high degree of overlapping of chambers. *25*, Apertural view of broken specimen showing incompletely fused siphon at the apertural opening and complete fusion slightly lower and inside the chamber. (p. 476)

incompletely fused leaving two inwardly projecting structures somewhat resembling teeth, foramina of the subjacent chambers at approximately right angles to each other.

Dimensions of holotype (USNM 103963): length 1.90 mm.; diameter 0.70 mm. Holotype from the Upper Cretaceous "*Clavulina* shale," sample 154-A, Square Mile 14–N–27, in Quebrada Chungo, 2 miles east of Redonda, Department of Piura, northwestern Peru.

This species differs from *S. cretacea* Cushman in having more inflated chambers, no costae, a much longer neck, and much more strongly retroflexed sutures. It is also considerably larger. This species is named in honor of Dr. Pedro J. Bermúdez.

SIPHOGENERINOIDES BERMÚDEZI PERUVIANA Stone, n. var.
Plate 71, figures 17–19

The variety differs from the typical *S. bermúdezi* by its smaller size and in having short, moderately coarse costae covering all but the last-formed chamber of the test. The costae are always discontinuous over the sutures, which are more sharply depressed than in *S. bermúdezi*.

Dimensions of holotype of variety (USNM 103965): length 1.50 mm.; diameter 0.47 mm. Holotype from the Upper Cretaceous "*Clavulina* shale," sample 115, 1 mile west of Pazul, Department of Piura, northwestern Peru.

SIPHOGENERINOIDES LANDESI Stone, n. sp.
Plate 72, figures 13–17

Test elongate, circular in transverse section, sides of megalospheric form nearly parallel, microspheric form gently tapering to a blunt point, greatest diameter near the apertural end; initial chambers of the microspheric form distinctly triserial followed by a short series of biserial chambers and then uniserial, megalospheric form with a large proloculum followed by a very short series of irregularly arranged uniserial chambers and then symmetrically uniserial; chambers inflated, indistinct toward the initial end but generally distinct toward the apertural end, chambers strongly overlapping; sutures indistinct toward the initial end but clearly visible, very strongly depressed and highly retroflexed toward the apertural end, marked retroflexion of sutures follows the course of the costae; wall thick, calcareous, perforate, highly ornamented by 10 to 14 very thick, coarse, high costae continuous over the sutures and disappearing about half to two-thirds of the way up the test, in the last few chambers the costae are replaced by highly retroflexed sutures aligned with the course of the costae, some specimens with a few discontinuous minor costae lying between the major costae; internal siphon reaching from the initial chambers to the last-formed chamber of the test, siphon twisting approximately 90° per chamber and forming a small, slightly elongate opening lying outside the aperture and tangent to its concave edge, unattached upper edge of siphon formed by the lip on the concave edge of the aperture, other edge of siphon continuous with the septal face of the last-formed chamber, same height as septal face and slightly lower than unattached edge of siphon, without lip; aperture central, terminal, gently arcuate, without neck and only a slightly thickened lip, which is usually completely fused on the concave side, with small opening lying outside and tangent to the concave edge of the aperture.

Dimensions of holotype (USNM 103972): length 1.93 mm.; diameter 0.70 mm. Holotype from the Upper Cretaceous "*Clavulina* shale," sample 76-J, Square Mile 14–N–25, one-half mile north of Redonda, Department of Piura, northwestern Peru.

This species most closely resembles *S. ewaldi* (Karsten) from which it differs by being stubbier with fewer and much coarser and more highly raised longitudinal costae, which die out and are replaced by strongly retroflexed sutures aligned with the course of the costae.

This species is named in honor of Dr. R. W. Landes.

SIPHOGENERINOIDES RETICULATA Stone, n. sp.
Plate 72, figures 18–25

Test elongate, stubby, sides gently curved, initial end of microspheric form pointed, megalospheric form with broadly rounded initial end, greatest diameter near the central portion of the test; initial chambers of the microspheric form distinctly triserial

followed by a short series of biserial chambers and then uniserial, megalospheric form with a very large rounded proloculum, a short series of biserial chambers and then uniserial; chambers very indistinct, inflated, overlapping irregularly to an extremely high degree throughout; sutures distinct, raised and thickened, very strongly retroflexed and fused together resulting in a gridlike arrangement of raised ridges on the exterior of the test; internal siphon connecting the initial chambers with the last-formed chamber, siphon twisting through about 90° per chamber and forming a small separate opening outside and tangent to the concave edge of the aperture, unattached upper edge of siphon formed by the apertural lip of the concave edge of the aperture, other edge continuous with the septal face of the last-formed chamber, same level as septal face and very slightly lower than the unattached upper edge of the siphon, without lip; aperture central, terminal, arcuate, without neck but bounded by a slightly thickened lip, lip on the concave edge of the aperture often broken or incompletely fused leaving two toothlike projections, which extend slightly into the apertural opening, with a small separate opening lying outside and tangent to the concave edge of the aperture.

Dimensions of holotype (USNM 103976): length 2.17 mm.; diameter 0.77 mm. Holotype from the Upper Cretaceous "*Clavulina* shale," sample 76-I, Square Mile 14–N–25, one-half mile north of Redonda, Department of Piura, northwestern Peru.

This species sometimes is very large but the holotype is of average size. The unusual degree of retroflexion of the sutures and their fusion, forming a network of raised ridges on the exterior of the test, makes this species entirely different from any described form. Thin sections suggest that some chambers are completely enveloped by later chambers, but this is only due to the orientation of the specimen, which causes the section to cut some of the long downward projecting protuberances which strongly overlap and partially obscure the subjacent chamber. The chambers of this species are quite low and the uppermost unattached edge of the siphon is seldom completely fused, though a true closed siphon is formed inside the chamber.

SIPHOGENERINOIDES REVOLUTA Stone, n. sp.
Plate 72, figures 1–7

Test elongate, stubby, slightly tapering, microspheric form with a pointed initial end, megalospheric form with a broadly rounded initial end, greatest diameter near the central portion of the test; initial chambers of the microspheric form distinctly triserial followed by a short biserial stage and then uniserial, megalospheric form with a large rounded proloculum followed by a short series of biserial chambers and then uniserial; chambers indistinct, slightly inflated, overlapping very irregularly to an unusually high degree throughout; sutures distinct, depressed, not thickened, strongly retroflexed and fused together resulting in a gridlike appearance of the exterior of the test; wall thin, calcareous, perforate; internal siphon connecting the initial chambers with the last-formed chamber, siphon twisting approximately 90° per chamber, uppermost end of siphon forming a small separate opening lying outside and tangent to the concave edge of the aperture, unattached upper edge of the siphon formed by the apertural lip on the concave side of the aperture, other edge of siphon continuous with the septal face of the last-formed chamber, same level as the septal face and slightly lower than the unattached edge of the siphon, without a lip; aperture central, terminal, arcuate, without neck but bounded by a slightly thickened lip only very slightly elevated above the level of the septal face, lip on the concave edge of the aperture often broken or incompletely fused, with small opening lying outside and tangent to the concave edge of the aperture.

Dimensions of holotype (USNM 103978): length 1.30 mm.; diameter 0.52 mm. Holotype from the Upper Cretaceous "*Clavulina* shale," sample 76-J, Square Mile 14–N–25, one-half mile north of Redonda, Department of Piura, northwestern Peru.

This species most closely resembles *S. reticulata* but differs in being smaller, having depressed and unthickened sutures and chambers, which are not so inflated. The holotype is of average size.

The development of an unusually high degree of retroflexion of the sutures and overlapping of the chambers in long finger-

like protuberances is very marked in this species as in *S. reticulata*. The chambers are very low. Thin sections reveal an internal structural condition similar to that found in *S. reticulata*. An examination of several hundred specimens of each of these forms has proved them to be distinct.

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Miller and Youngquist, Cretaceous Ammonite

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Miller and Youngquist, Cretaceous Ammonite

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A GIANT AMMONITE FROM THE CRETACEOUS OF MONTANA

A. K. MILLER AND WALTER YOUNGQUIST
State University of Iowa, Iowa City, Iowa

ABSTRACT—A fairly complete rather well preserved ammonite that is considerably more than a meter in diameter is illustrated and described. This specimen came from the Eagle sandstone of south-central Montana, and it represents a new species of the genus *Parapuzosia*.

DURING the summer of 1945, Ernest Schaak of Wyola, Montana, found a large ammonite in the basin between the northern Bighorns and the Wolf Mountains of south-central Montana. He enlisted the aid of F. Howard Brady of Sheridan, Wyoming, who recognized the general affinities and the uniqueness of the specimen. Brady also helped to remove it from the enclosing strata, and he completed arrangments to have it deposited at the State University of Iowa, where it became available to us for study. He states that it was found "in place" in the "topmost zone of the Eagle sandstone," and that originally it was intact, though part of it was inadvertently fragmented before the nature of the specimen became apparent.

Insofar as we have been able to ascertain, no ammonites of comparable dimensions have been described previously from the northern Great Plains or the northern Rockies. However, Meek (1876, p. 465) states that large examples of *Placenticeras placenta* (Dekay), to which specimens from various parts of North America have in the past been referred, "attain 2 feet or more in their greatest diameter." He adds (p. 468) that one of these "nearly 2 feet in diameter" was found in South Dakota, and that he had a "large specimen" from Minnesota; and Weller (1907, p. 830) indicates that individuals are known from New Jersey that reach "a diameter of 400 mm. or more." Reeside (1927, p. 30) states that *Placenticeras meeki* Boehm, which is widely distributed in the Upper Cretaceous of western United States (New Mexico to Montana), includes specimens "attaining a very large size, as much as 600 mm. in diameter," and Elias (1933, p. 331) reported some fragments from Kansas "which indicate that the species attained as large a size as 3½ feet in diameter."

The occurrence of exceptionally large specimens in the Cretaceous of southwestern United States and northern Mexico has been recorded by several authors. In his well-known *Handbook of Texas Cretaceous fossils*, Adkins (1928, pp. 220, 232) refers to Shumard's statements that the largest Texas Cretaceous ammonites known to him were *Desmoceras? brazoense* (Shumard), one type specimen of which is "21 inches in diameter," and *Pervinquieria vespertina* (Morton), specimens of which "were found to measure nearly 3 feet in diameter, and estimated to weigh upwards of 200 pounds." Shumard (1854, p. 183) stated that the latter is "the largest species of Ammonite that has hitherto been found in the United

EXPLANATION OF PLATE 73

FIGS. *1, 2*,—*Parapuzosia bradyi* Miller and Youngquist, n. sp. Lateral view of the holotype, ×0.11; and ventral view of the adoral portion of the phragmacone of the same specimen, ×0.2; from the Eagle sandstone near Wyola, Montana. (p. 481)

EXPLANATION OF PLATE 74

FIGS. *1, 2*—*Parapuzosia bradyi*, n. sp. Two views of the phragmacone of the holotype, from the Eagle sandstone near Wyola, Montana. *1*, All but the adapical half of the outer volution of the phragmacone ×0.2. *2*, The opposite side of the specimen shown by figure 1 of the preceding plate, with almost all of the living chamber removed, ×0.14; the details of the sutures have been lost through weathering. (p. 481)

States." Both of these forms are from the lower part of the Washita group. Scott and Moore (1928, pp. 273–279) have described still larger ammonites from the Upper Cretaceous Austin chalk of Texas. They say that the largest form they have seen from that state is *Parapuzosia bosei* Scott and Moore. One of the type specimens of that species is 950 mm. in diameter. It is septate throughout and therefore represents only phragmacone. Another of the figured types, which was not extracted from the matrix, is "4 ft. 9 in. [about 1448 mm.] in diameter." The holotype of a congeneric form, *P. americana* Scott and Moore from the same general locality and horizon, is 1030 mm. in diameter—the living chamber of this specimen is incomplete, and it was estimated that the "entire shell would probably have measured 4½ feet in diameter." The authors of these two species mention that there is a locality in northern Mexico, across the river from Eagle Pass, where gigantic forms, presumably belonging in one or both of these species, occur in great profusion.

"The largest species of cephalopod yet seen in the Cretaceous of the Pacific Coast" region of North America, according to Anderson and Hanna (1935, p. 19), is their species *Parapachydiscus catarinae* of the Senonian horizon in Baja California and California. These authors state that the holotype of that species, though septate throughout, attains a diameter of 19.8 inches (50.3 cm.), and they add that "if the body-chamber occupied only one-quarter of a whorl the diameter would be 26 inches, or if it extended only 24 inches from the last septum, the diameter would be 28 inches."

Brazilian Cretaceous ammonites are known particularly through the studies of Maury (1930). The largest specimen in her extensive collections, the holotype of *Parapachydiscus brasiliensis* Maury, has a diameter of 370 mm.

New Zealand has yielded a number of Upper Cretaceous ammonoids, which were monographed by Marshall in 1926. He states (p. 188) that one of the fragmentary type specimens of his species, *Parapachydiscus rogeri*, "is entirely septate, and it is probable that the complete individual with the body-chamber would be as much as 774 mm. in diameter."

In his classical report on Indian Cretaceous ammonites, Stoliczka (1865, p. 134) states that to his species, *Ammonites denisonianus*, "belongs the largest Ammonite yet found in Southern India, the diameter being more than three feet," or 945 mm., to be exact. Nowak (1913, pp. 349–350) places this species in *Parapuzosia;* however, Spath (1921, p. 225) states that it is pre-Senonian, and presumably, therefore, he believes that it is improbable that this form belongs in the genus to which Nowak assigned it. Perhaps it should also be mentioned that another large specimen from the same general horizon and locality, which Stoliczka (1865, p. 135) refers to *Ammonites planulatus* Sowerby, is 800 mm. in diameter.

From the Senonian of Zululand in South Africa, Spath (1921) has illustrated and described a completely septate specimen of *Parapuzosia* that is 670 mm. in diameter, and he mentions representatives of *Parapachydiscus*, one of which has whorls that are at least 260 mm. high and 200 mm. wide, whereas another is "probably of a diameter of about 600 mm." Nearby Mozambique has yielded *Lytodiscus* ["*Pachydiscus*?"] *conduciensis* (Choffat), a fragmentary specimen of which was estimated by Choffat (1903, p. 18) to have had a diameter of at least 1080 mm. when complete. Large ammonites are also known to occur across the straits in Madagascar. That is, Boule, Lemoine, and Thevenin (1906, p. 192, pl. 17, fig. 5) have illustrated and described from the Senonian of that island part of a phragmacone that is stated to be some 600 mm. in diameter. They called it (on the plate legend) "*Desmoceras* (*Puzosia*) cf. *Gaudama* Forbes," but as Spath (1921, pp. 224–225) has indicated, it is almost certainly distinct from Forbes' species, though both belong in the genus *Parapuzosia*.

Still larger ammonites have long been known from Europe. For example, in 1895 Landois illustrated and described a giant specimen from the Senonian of Westphalia that is 1800 mm. in diameter, and he estimated that when the living chamber of this individual was complete its maximum diameter was some 2550 mm.—at the junction of the phragmacone and the living chamber the conch is 550 mm. high. On the advice of Zittel, Landois referred this specimen to the genus *Pachydiscus* and coined the name *P. seppenradensis* for it and another large speci-

men from approximately the same horizon and locality. Nowak (1913, p. 365) has indicated that this species may possibly belong in *Parapuzosia*, but Spath (1921, p. 226) does not agree with this generic assignment, Insofar as we have been able to ascertain. this form is easily the largest one mentioned in the literature available to us, which, unfortunately, is not very complete. Clearly the Senonian was the time of giant ammonites all over the world, though, as is evident from the writings of Fraas (1891) and others, large individuals are known from several horizons in the Jurassic and other portions of the Mesozoic.

Acknowledgment is due to Mr. F. Howard Brady of Sheridan, Wyoming, for calling to our attention and helping us secure the specimen on which this study is based; to Professor Gayle Scott of Fort Worth, Texas, for advice in regard to the literature; to Miss Mary G. Allen of Iowa City, Iowa, for retouching our photographs; and to the Graduate College of the State University of Iowa for financial assistance.

Genus PARAPUZOSIA Nowak, 1913

Genotype, *Sonneratia daubrêei* Grossouvre

As has long been recognized, this genus belongs in the Desmoceratidae of Zittel. When Spath (1922, pp. 120–136) revised that family, he divided it into several subfamilies, one of which he called Puzosinae. In this subfamily he included *Parapuzosia* Nowak, *Schlüteria* Grossouvre, *Hauericeras* Grossouvre, and four then new genera.

Spath pointed out that

> Nowak introduced his genus *Parapuzosia* for ammonites of the "*denisoni*"-type, and he erroneously thought that they could be traced from the Cenomanian to the uppermost Cretaceous. It might, of course, be held that *A. denisonianus*, Stoliczka, is thus the genotype; but this species is not cogeneric with *Parapuzosia daubrêei* (Grossouvre), the only species described and figured by Nowak, so that the writer selected this Santonian form as the type of the genus *Parapuzosia*, which also should include *Parap. leptophylla* and *P.* (?) *icenica*, Sharpe sp., *P. corbarica*, Grossouvre, sp., *P. gaudama*, Forbes sp., *P. indopacifica*, Kossmat sp. and *P. stobaei*, Nilsson sp., the latter possibly transitional to *Parapachydiscus*.

Adkins (1928, p. 223) states that *Parapuzosia* "in general differs from *Parapachydiscus* in being more compressed laterally, in having wider umbilicus, and in having remote curved ribs." Spath (1921, p. 226) indicates that the ornamentation of the inner whorls of forms like the one we are describing show that they belong in *Parapuzosia* rather than *Parapachydiscus*, and he (1922, p. 127) states that "*Parapuzosia* has the course of the radial line and the constrictions of the strongly projected *subplanulata*-type different from the straight ornamentation of the Campanian." For the sake of completion, it should be mentioned that *Ammonites denisonianus* Stoliczka is the genotype of *Pachydesmoceras* Spath, 1922.

As was noted by Scott and Moore (1928, p. 275), *Parapuzosia* "seems to include forms of quite variable whorl section." This fact may be explained in part, at least, by Spath's conclusion that the genus is polyphyletic.

It is, to be sure, in many cases difficult to determine accurately the generic affinities of species from the published illustrations and descriptions of them. Nevertheless, it is probably worth noting that various authors have referred to the genus *Parapuzosia* specimens from England, France, Germany, Sweden, Bohemia, Poland, Bulgaria, India, South Africa, Madagascar, and New Zealand, as well as the United States and Mexico. All of these are from the Upper Cretaceous. Most of them came from strata that are Senonian in age, but a few are from pre-Senonian, that is, Turonian, horizons.

PARAPUZOSIA BRADYI Miller and Youngquist, n. sp.

Plate 73, figures 1, 2; plate 74 figures 1, 2; plate 75, figures 1–3

This species is based on a single specimen, which is fairly complete and rather well preserved. Its maximum diameter, measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen, is about 1125 mm. As shown by the accompanying illustrations, the conch consists of more than three and one-half volutions—the extreme adapical portion of the specimen was not removed from the matrix, as a transverse break revealed that much of the structure of that part of the conch had been lost. The adoral half volution of the holotype is nonseptate and therefore presumably represents living chamber.

The conch is thickly subdiscoidal in shape,

as the whorls are compressed and flattened laterally, rather narrowly rounded ventrally, and deeply impressed dorsally. The maximum height of the conch of the holotype measures about 430 mm., the corresponding width (which is attained somewhat dorsad of the midheight of the whorl and which may have been decreased somewhat by lateral crushing during fossilization) about 335 mm., and the depth of the impressed zone about 140 mm. Corresponding measurements at the junction of the phragmacone and the living chamber are about 385 mm., 265 mm., and 115 mm., respectively. At the adoral end of the antepenultimate volution of the holotype (pl. 75, fig. 3), the conch is about 107 mm. high and 83 mm. wide., and the dorsal impressed zone is about 30 mm. deep. Apicad of this place, the conch appears to become somewhat more narrowly rounded ventrally and relatively narrower.

The umbilicus is moderately large and that of the holotype attains a maximum diameter of some 325 mm. The umbilical walls are rather narrow but are steep and are almost normal to the flattened lateral zones of the conch. The maximum height attained by the umbilical walls of the holotype measures about 60 mm. The umbilical shoulders are abruptly rounded and are fairly distinct.

The conch bears distinct transverse ornamentation. The smallest visible volution of the holotype (pl. 75, figs 1, 2) is marked by numerous small but distinct low rounded ribs, which are somewhat wider than the intervening grooves. These ribs form rounded ventral salients and similar but more broadly rounded lateral sinuses. On the next volution, the antepenultimate, the surface of the test (but not the internal mold) bears similar small ribs, and in addition there are much larger and more widely spaced ribs that are low and rounded and not very conspicuous on either the surface of the test or the intermediate layers of it. These ribs are most prominent on the lateral zones of the conch, but they extend in a subdued form across the ventral zone and possibly the umbilical walls. In each of the intervening spaces there are intercalated three or four smaller ribs, which are confined to the ventral and ventrolateral zones of the conch. All of these ribs are parallel, and they appear to be most prominent on the surface of the test. It should also be noted that fragments of the test show that its surface is marked by fine growth lines, parallel to the ribs, and that near the midlength of the antepenultimate volution of the holotype there are preserved several sinuous transverse constrictions, which are likewise parallel to the ribs.

On the penultimate volution of the holotype, the conch bears broad, rounded ribs or bulges, which are largely confined to the lateral zones, becoming indistinct on the ventrolateral and dorsolateral zones. These ribs become increasingly inconspicuous adorally but can be discerned throughout most if not all of the ultimate volution. At maturity on the surface of the test there are between these ribs and parallel to them numerous small ridges, which presumably represent increments of growth. The surface of the adoral half of the living chamber has been weathered to such an extent that the details of its ornamentation are essentially gone.

As shown by figure 2 on plate 74 and figures 2 and 3 on plate 75, portions of the sutures are quite distinct on the holotype. However, at no place on this specimen is it possible to trace a single suture throughout a distance approaching its entire length. Nevertheless, it is clear that the sutures of this form are quite comparable to those of the genotype, *Parapuzosia daubréei* (Grossouvre) of the Senonian of central Europe, which have been well illustrated by Nowak (1913, pl. 44, fig. 40)—they consist of rather short but finely divided elements, the ventral lobe is relatively shallow, and the first lateral lobe is considerably deeper and has peculiar asymmetrical divisions.

The siphuncle of this species is small and is ventral and marginal in position, as is that of related forms. Its size and position are illustrated by figure 1 on plate 74 and figures 1 and 3 on plate 75.

Remarks.—The smallest whorl that is visible in the holotype of this species is strikingly similar to an inner volution of a large (670 mm. in diameter) septate representative of *Parapuzosia* from the Upper Cretaceous Senonian of South Africa that was illustrated and described by Spath (1921, pp. 224–226, pl. 19, fig. 2; pl. 20, figs. 1, 1a; pl. 24, fig. 3). Furthermore, as

Miller and Youngquist, Cretaceous Ammonite

noted by that author, the ribbing and compressed aspect of the inner whorls suggest an affinity with *P. gaudama* (Boule, Lemoine, and Thevenin) [not Forbes] of Madagascar. The South African form appears to differ from ours particularly in the absence of low ridges or bulges on the lateral zones of the mature portions of its conch. As was pointed out by Spath (1921, p. 225),

> the bulges on the inner portions of the lateral area [in forms like this one are] reminiscent at once of *Parapuzosia leptophylla* (Sharpe) and of certain *Pachydiscus* and *Parapachydiscus*.

Insofar as we have been able to ascertain, only two American species have previously been referred to the genus *Parapuzosia*. These are *P. americana* Scott and Moore and *P. bosei* Scott and Moore of the Upper Cretaceous Austin chalk of Texas and probably northern Mexico. In size and general physiognomy, both of them resemble the species under consideration, and the surface ornamentation of at least the outer volution of their conchs, though different in detail, is in general quite comparable.

Occurrence.—Upper part of Eagle sandstone in NW¼ sec. 8, T. 9 S., R. 35 E., southwest of Wyola, Big Horn County, south-central Montana. Thom, Hall, Wegemann, and Moulton (1935, p. 57) list a variety of fossils from the massive Eagle sandstone at this locality, including representatives of the cephalopod genera *Eutrephoceras*, *Baculites*, *Placenticeras*, and *Scaphites*. In 1927 Reeside illustrated and described numerous cephalopods from the Eagle sandstone and related formations.

It should probably be mentioned that the living chamber of the holotype is filled with light-gray calcareous shale, in which is imbedded a belemnite and an 11-inch fragment of petrified wood. The rest of the specimen is entirely calcareous, and it consists of the original shell, or a replacement thereof, with many of the camerae lined (but largely unfilled) with crystalline calcite.

Holotype.—State University of Iowa, 1073.

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EXPLANATION OF PLATE 75

FIGS. *1–3*—*Parapuzosia bradyi* Miller and Youngquist, n. sp. Three views of the antepenultimate volution (and a portion of the preceding volution) of the holotype, from the Eagle sandstone near Wyola, Montana, ×0.5. (p. 481)

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LATE TERTIARY FRESH-WATER MOLLUSKS FROM SOUTHEASTERN IDAHO

TENG-CHIEN YEN
Philadelphia, Pa.

THIS PAPER is based on material collected by Mr. Vincent E. McKelvey, of the United States Geological Survey, in the NE¼ NW¼ sec. 8, T. 12 S., R. 43 E., 9 miles northwest of Montpelier, Bear Lake County, Idaho. The fossils are embedded in a coarse light-gray massive oolitic calcareous sandstone, assigned by G. R. Mansfield (1927, pl. 9) to the "Salt Lake formation." The stratigraphic position of this fossiliferous bed within the assigned formation is unknown, since the section has not been measured. The formation in the area is at least several hundred feet thick and consists of interbedded tuffaceous conglomerates, calcareous sandstones and tuff, which dip as much as 50° eastward.

The molluscan fauna, as far as now identified, consists of two undeterminable species of the pelecypod *Pisidium* and 19 species of gastropods representing 10 genera in five families. Among them 11 species and one subspecies are considered to be new. In addition to the determined species, a few forms are represented in the present collection by immature and imperfect specimens only and are not included in this paper. However, they seem to indicate a richer fauna in this deposit that may be exploited by further collecting.

In completing this paper, I wish to express my thanks to the administrative officers of the Geological Society of America for their encouragement by making the grant from the Penrose Bequest to support my research project. To the authorities of the U. S. National Museum and the Academy of Natural Sciences of Philadelphia, in which institutions this work has been carried on, I extend my thanks for their kindness. To Dr. John B. Reeside, Jr., of the U. S. Geological Survey, my thanks are due for his kindness in reading this manuscript, for his valuable suggestions, and also for his courtesy in providing some of the research facilities, and to Dr. Henry A. Pilsbry of the Academy of Natural Sciences of Philadelphia, for his expert advice, which has indeed improved the contents of this paper.

COMPOSITION AND AGE OF THE FAUNA

The collection consists of the following species of fresh-water mollusks:

Sphaeriidae
- *Pisidium* sp. undet.
- *Pisidium* sp. undet.

Valvatidae
- *Valvata multicarinata* Yen, n. sp.
- *Valvata* cf. *V. octonaria* Brusina.
- *Valvata* sp. undet.

Amnicolidae
- *Amnicola micra* Yen, n. sp.
- *Brannerillus physispira* Hannibal.
- *Brannerillus acutispira* Yen, n. sp.
- *Brannerillus idahoensis* Yen, n. sp.

Lymnaeidae
- *Lymnaea idahoensis* Yen, n. sp.
- *Lymnaea petaluma* Hanna.
- *Lymnaea fluminicoloides* Yen, n. sp.
- *Lymnaea umbilicalis* Yen, n. sp.

Physidae
- *Physa* sp. undet.

Planorbidae
- *Armiger subcostatus* Yen, n. sp.
- *Armiger subcostatus obsoletus* Yen, n. subsp.
- *Vorticifex tryoni* Meek.
- *V. tryoni concava* Meek.
- *Carinifex brevispira* Yen, n. sp.
- *Planorbifex idahoensis* Yen, n. sp.
- *Papyrotheca idahoensis* Yen, n. sp.

The molluscan species seem to indicate clearly that the fossil bed is a lacustrine deposit. The presence of numerous species, prolific in individuals, generally indicates as a habitat area a sizable lake, and the abundant species of pulmonates in the fauna suggest that the deposit represents a shallow-water facies of this large extinct body of water. The pulmonate snails generally dwell among aquatic vegetation, and they are at least part of the time air-breathing. In addition to the mollusks, ostracodes are also very common in the deposit, though fossil

remains of other aquatic animals seem to be very scarce and, so far as the present collection is concerned, nothing else has been found.

The age of the Salt Lake formation, as presented in the literature, is in some confusion. In the first use of the name as "Salt Lake group," by Hayden (1869, p. 92), it was assigned to the "upper Tertiary," and stated to include deposits in Salt Lake Valley. Peale (1879, pp. 588, 640) introduced it into the Idaho area, and it was subsequently used in a loose sense and assigned to the "Pliocene (?)." Mansfield (1920, and 1927, pp. 110–112) used "Salt Lake formation," citing G. K. Gilbert as showing the deposits to antedate Great Salt Lake and citing fossils identified by W. H. Dall as of Eocene age and others as probably of Pliocene age. Mansfield indicates that at places the deposits are definitely younger than the Wasatch formation (lower Eocene) and concludes that they may be of Pliocene age, as earlier assumed.

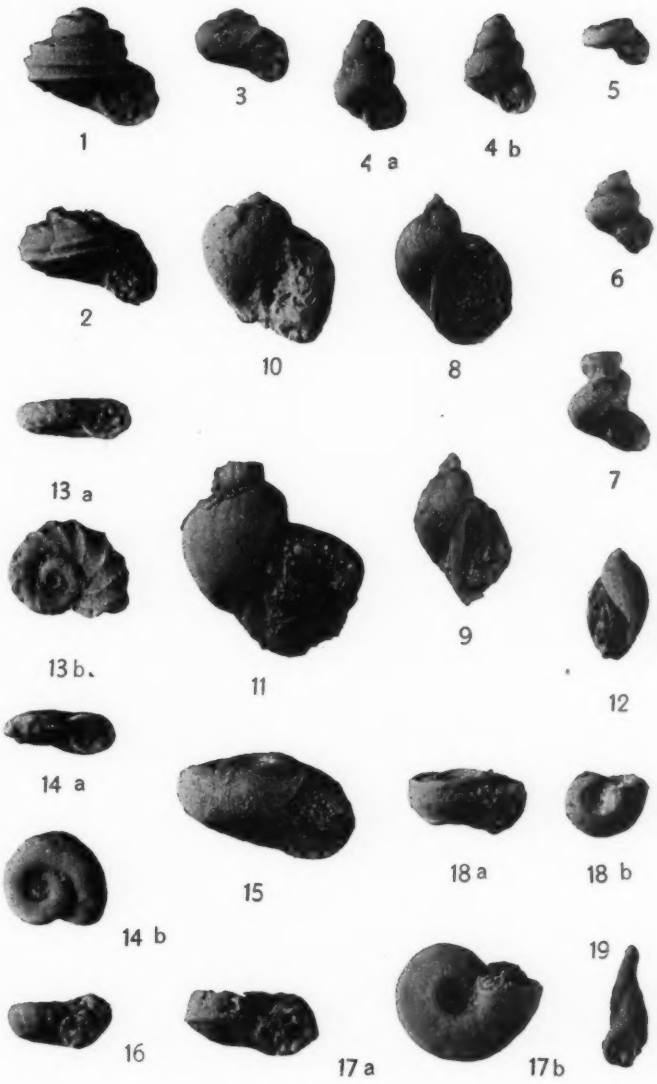
Judged by two collections of fresh-water mollusks made by W. W. Rubey and by E. M. Parks in the NE¼ sec. 13, T. 33 N., R. 119 W., Lincoln County, Wyoming, which is about 37 miles northeast of Montpelier, Idaho, and assigned tentatively to the "Salt Lake beds" (Mansfield, 1916, pl. 12), that name has been applied to units of different ages. The collection from western Wyoming, though small, yields molluscan species indicating a much younger age than that of the fauna described in this paper.

The age assignment given here to the deposit in Bear Lake County, Idaho, is based almost entirely on the evidence of the mollusks. The species of the assemblage appear to be closely related to the congeneric forms that have been described from Sarmatian and Pontian beds (upper Miocene) of Europe. *Lymnaea idahoensis*, n. sp., is close to *Lymnaea zelli* Hoernes, from the Sarmatian exposed near Hoeglein, Feldberg, in the Vienna Basin, and also to *Lymnaea socialis* (Schueler) Zieten from the same formation but near Steinheim on the Albuch, Germany. Such forms as *Brannerillus idahoensis*, n. sp., *Armiger subcostatus*, n. sp., *Armiger subcostatus obsoletus*, n. subsp., and *Carinefex brevispira*, n. sp., of the present collection seem to be related to *"Planorbis" denudatus* Hilgendorf, *"Planorbis" costatus* Klein, *"Planorbis" minutus* Higlendorf, and *"Planorbis" discoideus* Hilgendorf from the Sarmatian beds exposed near Steinheim on the Albuch. *Valvata multicarinata*, n. sp., and *Papyrotheca idahoensis*, n. sp., resemble *V. palmotici* Brusina and *P. pseudogyra* Brusina, which have been described from Pontian beds in the Balkan States. As may be noted, the nomenclature used here for the species of Steinheim fossils has been quoted from Hyatt (1880) for the time being. Any revision of their status will have to involve a discussion of their historical development which is beyond the scope of the present paper.

On the other hand, the present collection of mollusks, however characteristic its spe-

EXPLANATION OF PLATE 76

FIG. *1*—*Valvata multicarinata* Yen, n. sp. ×4. (p. 487)
2—*Valvata* cf. *V. octonaria* Brusina. ×4. (p. 488)
3—*Valvata* sp. undet. ×6. (p. 488)
4a, b—*Amnicola micra* Yen, n. sp. ×6. (p. 488)
5—*Brannerillus physispira* Hannibal. ×6. (p. 489)
6—*Brannerillus acutispira* Yen, n. sp. ×6. (p. 489)
7—*Brannerillus idahoensis* Yen, n. sp. ×6. (p. 489)
8—*Lymnaea idahoensis* Yen, n. sp. ×2. (p. 490)
9—*Lymnaea petaluma* Hanna. ×2. (p. 490)
10—*Lymnaea fluminicoloides* Yen, n. sp. ×4. (p. 490)
11—*Lymnaea umbilicalis* Yen, n. sp. ×2. (p. 490)
12—*Physa* sp. undet. ×6. (p. 491)
13a, b—*Armiger subcostatus* Yen, n. sp. ×6. (p. 491)
14a, b—*Armiger subcostatusa obsoletus* Yen, n. subsp. ×6. (p. 491)
15—*Vorticifex tryoni* Meek. ×2. (p. 491)
16—*Vorticifex tryoni concava* Meek. ×6. (p. 492)
17a, b—*Planorbifex idahoensis* Yen, n. sp. ×6. (p. 492)
18a, b—*Carinifex brevispira* Yen, n. sp. ×4. (p. 492)
19—*Papyrotheca idahoensis* Yen, n. sp. ×6. (p. 493)



Yen, Late Tertiary Mollusks from Idaho

cies are, shows no isolation of its elements from the molluscan faunas that are known in various late Tertiary strata exposed on this continent. One species of *Lymnaea* seems to be identical with *Lymnaea petaluma* Hanna, described from a fossil bed near Petaluma, Sonoma County, California, which has been considered a "fresh-water and brackish phase of the marine San Pablo of Upper Miocene." The carinated forms of *Valvata* in the present collection remind one of "*Valvata oregonensis* Hanna," which was described from the "supposed Pliocene deposits in the vicinity of Warner Lake," in eastern Oregon. According to Hanna (1922), "*V. oregonensis*" was found in association with *Parapholyx packardi*, *Lanx* sp., *Pisidium* sp., *Planorbis scabiosus*, *Paludestrina micrococcus*, *Vorticifex condoni*, and *Carinifex*? sp. With the exception of *Lanx* in the Oregon beds and *Lymnaea* in the present collection, the combination of genera found in Oregon agrees in general with the composition of the fauna obtained from the fossil bed in southeastern Idaho.

One or two forms in the present collection may be related to congeneric forms that Chamberlin and Berry (1933) described from an outcrop near Collinston, Utah. However, the authors of that paper assigned to their species a Pliocene age and considered the fossil beds to be equivalent to the "Humboldt group." Their conclusion was based on King's report in 1878 and also on a comparison with the molluscan species that were described by Meek in 1870, but redescribed and illustrated in 1877, from Fossil Hill, Hot Spring Mountain (Kawsoh Mountains, according to Reeside) in Nevada.

It is perhaps well to note that the fossil beds exposed in the vicinity of Warner Lake in eastern Oregon are insufficiently known to be regarded as definitely of Pliocene age, and the age determination of the exposure near Collinston, Utah, if the deposit is equivalent to the "Humboldt group," is still an open question.

Assuming the age of the deposit under consideration to be upper Miocene, a number of relict forms would be expected in later deposits, such as those of Pliocene age, exposed elsewhere west of the continental divide. This supposition would seem to be verified by the presence of such a characteristic genus as *Brannerillus* Hannibal, which is represented by three species in the present deposit, in the Pliocene beds exposed in the Kettleman Hills near Coalinga, California, from which *Brannerillus physispira* Hannibal, *B. involutus*, *B. i. thremma*, and *B. i. praeposterus* of Pilsbry were described. Moreover, species of other genera, such as *Valvata*, *Amnicola*, *Armiger*, *Vorticifex*, and *Carinifex*, which are well represented in the Idaho deposit, are present, in associations similar to that here described, in Pliocene to Recent deposits in California. The close relationship with the faunas reported from younger formations of this continent would seem to imply merely continuity of ecologic factors, not identity of age.

From the foregoing comparison and discussion, in summary, it seems to the writer reasonable to assign the deposit from the locality northwest of Montpelier, Idaho, to the upper Miocene, because of (1) the resemblance of its individual species of mollusks to fossils described from the Sarmatian and Pontian beds of Europe, and (2) the occurrence in association of a number of closely related species in both the fossil assemblage in Idaho and Miocene formations in Europe.

SYSTEMATIC ACCOUNT OF SPECIES

Family SPHAERIIDAE

PISIDIUM, sp. undet.

A number of single valves and one complete specimen seem to resemble in general outline *Pisidium woodringi* Yen, described from the Idaho formation. The structure of the hinge is not well shown in these specimens.

Unfigured specimen: U. S. Nat. Mus. 559941.

PISIDIUM, sp. undet.

Two imperfectly preserved specimens are more compressed in outline and of larger size than the preceding form, but specific identification is not possible.

Unfigured specimen: U. S. Nat. Mus. 559942.

Family VALVATIDAE

VALVATA MULTICARINATA, Yen, n. sp.

Plate 76, figure 1

Shell of small size, widely umbilicated, with an elevated spire and descending body

whorl. The whorls are convex, rapidly increasing in size, coiling slightly obliquely below the periphery. The last whorl bears four strong primary carinae, uppermost one marking the shoulder, second one on the periphery, third just below the periphery, and lowermost around the umbilicus. The growth lines appear to be strong and distinct on the better-preserved part of the surface. The aperture is closely attached to the penult whorl, having its peristome continuous with polyangulated margin.

Altitude of holotype and paratype, 4.5 and 4.1 mm.; width, 5.0 and 5.0 mm.; diameter of aperture, 2.0 and 2.0 mm.; diameter of umbilicus, 2.3 and 2.3 mm.; number of whorls, 4.0 and 4.0.

Holotype: U. S. Nat. Mus. 559943; paratype: U. S. Nat. Mus. 559944.

This species is characterized by its prominent quadracarinate spirals and wide umbilicus. On some specimens, a secondary and less strongly developed carina occurs between the infraperipheral and the umbilical ones. Sometimes this secondary is only faintly traceable, and it is not observed on the shells of younger stage.

The species resembles closely in general outline and sculpture *Valvata palmotici* Brusina, which was described from the Pontian exposed near Poganac, Lepavina, Croatia. It differs, however, by its constantly higher spire, wider umbilicus and larger diameter of the shell with almost same number of whorls.

The systematic value of the spiral sculpture in Valvatidae seems uncertain. Some consider it a basis of specific difference, others allow its variation within a specific range. It may be noted that the difference in the stage at which it makes its appearance should be emphasized. Some spirals may be well developed on shells of young stages and may be considered primary, while others appear on shells of more mature individuals, usually between two primary spirals, and may be called secondary. Difference in number of the primary spirals may be considered a feature of specific importance. *Valvata tricarinata* Say and *V. bicarinata* Lea, which are often found in the same locality, furnish a good example—though other features are also noted, the main difference in shell characters of these two distinct species is the number of the primary spiral carinae.

VALVATA cf. V. OCTONARIA Brusina
Plate 76, figure 2

A single specimen measuring 3.1 mm. in shell altitude, 5.0 mm. in its width, 2.0 mm. in diameter of aperture, 2.5 mm. in diameter of umbilicus, has three to four whorls. The sculpture is essentially similar to that of the preceding species. As the degree of variation in elevation of spire and size of shell is not known, the specific identification is not satisfactory.

The preceding two species may possibly belong to *Tropidina* H. and A. Adams, which is generally considered as a subgenus of *Valvata* Mueller, with *Valvata tricarinata* Say as its genotype.

Figured specimen: U. S. Nat. Mus. 559945.

VALVATA, sp. undet.
Plate 76, figure 3

Three examples represent this form. The largest one measures 2.0 mm. in altitude of shell, 2.2 mm. in width, and has three whorls. The apex is rather blunt, the whorls are roundly convex and bear no spiral carinae. The aperture is almost circular in outline, with thin and continuous peristome.

All these features indicate the species to be a true *Valvata*. However, these are common characters of the genus, and a definite specific identification of this form will have to depend on more and better-preserved specimens.

Figured specimen: U. S. Nat. Mus. 559946.

Family AMNICOLIDAE
AMNICOLA MICRA Yen, n. sp.
Plate 76, figure 4

Shell rissoid in outline, small, narrowly umbilicated, having its spire higher than the body whorl. The whorls are convex, rapidly increasing in size, and separated by a strongly impressed suture. The sculpture consists of fine lines of growth only. Aperture ovate, narrower towards its posterior end; peristome thin and continuous, having its parietal wall well defined and sometimes slightly adnate.

Altitude of holotype and two paratypes, 2.9, 2.5, and 2.8 mm.; width, 1.8, 1.8, and

1.8 mm.; height of aperture, 0.9, 0.8, and 0.9 mm.; width of aperture, 0.6, 0.6, and 0.7 mm.; number of whorls, 4.0, 4.0, and 4.0.

This species resembles *Amnicola longiqua* Gould, a species commonly reported from Pliocene to Recent horizons, but it differs in its much smaller size and more narrowly conical spire. It differs from *Amnicola bithynoides* Yen, which was described from the Idaho formation exposed near Hammett, Idaho, also in its smaller size, thinner peristome and higher spire.

Holotype: U. S. Nat. Mus. 559947; paratypes: U. S. Nat. Mus. 559948, 559949.

BRANNERILLUS PHYSISPIRA Hannibal
Plate 76, figure 5

Brannerillus physispira HANNIBAL, 1912, Malac. Soc. London Proc., vol. 10, p. 191, pl. 8, fig. 28. —PILSBRY, 1934, Acad. Nat. Sci. Philadelphia Proc., vol. 86, p. 563, pl. 23, figs. 1, 2.

Two specimens, the more mature one measuring 2.2 mm. in altitude, 2.0 mm. in width, 1.0 mm. in diameter of aperture, and displaying $3\frac{1}{4}$ whorls, agree well with this species, known from Pliocene beds, except that they are smaller and have one whorl less. A few rib lines are present on the last part of body whorl. The younger specimen represents an example of a little more than the planorboid stage, with $2\frac{1}{3}$ whorls.

Figured specimen: U. S. Nat. Mus. 559950.

BRANNERILLUS ACUTISPIRA Yen, n. sp.
Plate 76, figure 6

Shell small, trochoid in outline, openly but narrowly umbilicated; spire conically elevated, body whorl descending and obtusely carinated at the periphery. The whorls are tubuloid, roundly convex, and rapidly increasing in size; apex scarcely raised; first whorl closely coiled, following whorls loosely coiled. The sculpture consists of fine growth lines only. Aperture roundly ovate, slightly oblique; peristome thin and continuous, having its parietal wall detached.

Altitude of holotype and paratype, 2.0 and 2.0 mm.; width, 1.7, and 1.6 mm.; diameter of aperture, 0.5 and 0.5 mm.; number of whorls, 3.0 and 3.0.

The species has a brief planorboid stage at the summit, which consists of about one volution, and its subsequent whorls are loosely coiled. These features differentiate this species from the preceding one as well as from *Brannerillus involutus* Pilsbry.

Holotype: U. S. Nat. Mus. 559951; paratypes: U. S. Nat. Mus. 559952.

BRANNERILLUS IDAHOENSIS Yen, n. sp.
Plate 76, figure 7

Shell small, ovate-oblong in outline, having an elevated spire and descending body whorl, rounded at its periphery. The whorls are tubuloid, roundly convex, and increase rather gradually in size. The first one and one-half whorls are closely coiled and constitute the planorboid stage of the shell; following whorls are rapidly detached from the preceding whorl. The sculpture consists of fine lines of growth, which are indistinctly traceable. The aperture is roundly ovate, distantly separated from the penultimate whorl; peristome thin and continuous.

Altitude of holotype and paratype, 2.5 and 2.6 mm.; width, 2.1 and 2.0 mm.; diameter of aperture, 0.5 and 0.5 mm.; number of whorls, $3\frac{1}{4}$ and $3\frac{1}{3}$.

The species differs from the preceding one by having one-half whorl more in the planorboid stage at its summit and the following whorls more loosely coiled, which gives the shell a more oblong outline.

Holotype: U. S. Nat. Mus. 559952; paratypes: U. S. Nat. Mus. 559954.

The younger forms of this species and the preceding two species remind one of "*Planorbis*" *denudatus* Hilgendorf (Hyatt, 1880, p. 60, pl. 4, fig. e), which was described from Sarmatian beds exposed near Steinheim on the Albuch, Germany. The mature examples of *Brannerillus idahoensis* resemble closely that species as illustrated by Hilgendorf himself in 1866 (pl. —, fig. 19). The morphological resemblance in shell features is difficult to deny, although the opinions in regard to their genetic relationship are so widely different.

With the exception of having a brief planorboid stage on the summit of the shell, species of *Brannerillus* hardly show any other similarity to members of Planorbidae. Pilsbry in 1934 pointed out that such a planorboid summit is found in species of *Fluminicola* and *Probythinella*. Moreover, species of *Baglivia* Brusina described from Pontian beds in the Balkan States seem also

to possess planorboid initial whorls. Therefore, as far as our present knowledge goes, it seems to be that *Brannerillus* is more possibly related to these above-mentioned rissoid groups rather than to genera of Planorbidae.

Family LYMNAEIDAE

LYMNAEA IDAHOENSIS Yen, n. sp.
Plate 76, figure 8

Shell roundly ovate, moderately inflated, having an exserted but not highly elevated spire and dilated body whorl. The whorls are convex, rapidly increasing in size and separated by an impressed suture. The sculpture consists of fine growth lines with occasional heavy rib lines. Aperture ovate in outline; outer lip thin with slightly expanded margin; inner lip moderately thick, nearly straight at columella. Umbilicus narrowly perforated.

Altitude of holotype, 11.0 mm.; width, 7.2 mm.; height of aperture, 7.8 mm.; width of aperture, 5.5 mm.; number of whorls, 3½.

The species seems to have the shell features of *Radix* Montfort, except the absence of a plait on the margin of the inner lip. *Radix* is generally believed to be Palaearctic rather than Holarctic in distribution in the Recent fauna. It is characterized by its exserted and low spire, dilated body whorl, and nearly straight columellar margin.

It resembles *Lymnaea socialis* (Schübler) Zieten and *Lymnaea zelli* Hoernes of Sarmatian beds in Europe, but it differs by its much smaller size in proportion to the number of whorls and straighter columellar margin.

Holotype: U. S. Nat. Mus. 559955; paratypes: U. S. Nat. Mus. 559956.

LYMNAEA PETALUMA Hanna
Plate 76, figure 9

Lymnaea petaluma HANNA, 1923, California Acad. Sci. Proc., ser. 4, vol. 12, no. 3, p. 37, pl. 2, figs. 3, 7.

The species seems to be represented here by immature examples, the largest of which measures 11.0 mm. in altitude of shell, 6.0 mm. in width; 7.0 mm. in height, 4.2 mm. in width of aperture; and has 3⅓ whorls. It is characterized by its scarcely convex whorls, slightly twisted and thickened columellar margin.

Figured specimen: U. S. Nat. Mus. 559958; unfigured specimens, U. S. Nat. Mus., 559958.

LYMNAEA FLUMINICOLOIDES Yen, n. sp.
Plate 76, figure 10

Shell small, almost imperforate, ovately globose in outline, with a short but exserted spire and laterally inflated body whorl. The whorls rapidly increase in size, early ones scarcely convex and separated by an incised suture. The sculpture consists of fine, wavy growth lines with occasional stronger rib lines. The rib lines are fewer on early whorls. Aperture laterally ovate in outline, having its outer lip thinly margined and inner lip appearing to be thickened, with a short, oblique columella.

Altitude of holotype and a paratype, 5.6 and 4.3 mm.; width, 4.1 and 3.7 mm.; height of aperture, 4.0 and 3.0 mm.; width of aperture, 3.0 and 2.2 mm.; number of whorls, 3.0 and 2⅘.

This species resembles in general outline *Lymnaea subbullata* Sandberger, which was described from lower Miocene beds in the western and central parts of Germany, however, it is readily distinguished by its apparently much smaller size and less inflated body whorl. Wenz included *Lymnaea subbullata* as a synonym of *Radix subovata eurygaster* (Boettger). I have not seen authentic specimens of either form, and my comparison is drawn only from descriptions and figures of the species.

Holotype: U. S. Nat. Mus. 559959; paratypes: 559960.

LYMNAEA UMBILICALIS Yen, n. sp.
Plate 76, figure 11

Shell large, thin, having a low but exsertedly elevated spire and laterally dilated body whorl. The whorls are convex, increasing rapidly in size, especially the last one, which is much more inflated than the penult one. The sculpture consists of fine, wavy lines of growth with occasional rather sharp rib lines on the body whorl. Aperture pyriform, with its peristome thin and nearly continuous, slightly reflected at margin of outer lip and somewhat produced at the basal margin. Umbilicus open and deep.

Altitude of holotype and two paratypes, 14.5+, 21.7, and 18.9+ mm.; width, 12.5,

16.2, and 15.2 mm.; height of aperture, 8.7, 16.0, and 15.0 mm.; width of aperture, 7.0, 12.8, and 11.0 mm.; number of whorls, last 3, 4+, and last 2.

Only one specimen with better preserved part of shell, and several internal molds represent this species, which seems to be characterized by its large size, laterally dilated body whorl, and open, deep umbilicus. The last mentioned feature is rarely encountered in species of Lymnaeidae.

The present generic status for this species must be considered as provisional. However, it seems beyond doubt to belong to a group related to *Radix* Montfort and *Galba* Schrank. More perfectly preserved specimens will provide more satisfactory identification.

Holotype: U. S. Nat. Mus. 559961; paratypes: U. S. Nat. Mus. 559962.

Family PHYSIDAE

PHYSA sp. undet.

Plate 76, figure 12

This forms seems to be represented here only by immature specimens, one well-preserved example measures 2.6 mm. in altitude of shell, 1.5 mm. in width, and has 2½ whorls. It is ovate in outline with a spire constituting about one-fourth of the entire altitude and narrowly dilated body whorl. The whorls are gently convex and separated by an impressed suture.

Although it seems certain that this small, sinistral form is a true *Physa*, its specific identification is for the time left undecided. As far as the specimens of the present collection show, it seems to be different from *Physa humerosa* Gould and *Physa wattsi* Arnold, which have been commonly reported from various beds of Pliocene to Recent times. It resembles in general outline *Physa nuttalli* Lea, which is a Recent species commonly reported in the western part of the continent, but their genetic relationship cannot for the present be satisfactorily established.

Figured specimen: U. S. Nat. Mus. 559963.

Family PLANORBIDAE

ARMIGER SUBCOSTATUS Yen, n. sp.

Plate 76, figures 13a, b

Shell of small size, ultradextral, perspectively umbilicate, having a nearly flattened or slightly sunken spire, and rapidly enlarged body whorl. The whorls are gently convex, rapidly increasing in size, and separated by a well-impressed suture. The whorl surface is marked by strong and well-spaced rib lines, nearly rounded or obtusely angulated at the periphery. The aperture is transverse-oval in outline, oblique, having a thin and continuous peristome.

Altitude of holotype and one paratype, 1.0 and 1.0 mm.; width, 2.8 and 3.0 mm.; diameter of umbilicus, 1.0 and 1.0 mm.; number of whorls, 2¼ and 2¾.

The species differs from *Armiger cristus* (Linné), which has been described from Pliocene to Recent deposits in Europe and North America, by its lower altitude of shell, stronger ribs, and wider umbilicus. It is different from "*Planorbis*" *costatus* (Klein), which was described from Sarmatian beds of Steinheim on the Albuch, by its larger size, with almost the same number of whorls, and less closely arranged rib lines.

Holotype: U. S. Nat. Mus. 559964; paratypes: U. S. Nat. Mus. 559965.

ARMIGER SUBCOSTATUS OBSOLETUS

Yen, n. subsp.

Plate 76, figures 14a, b

The shell is essentially similar to the preceding species, except that the rib lines are in some examples very obscure and in some nearly wanting. The body whorl is obtusely angulated at the periphery, and the aperture is decidedly oblique. The parietal wall is barely attached to the penultimate whorl.

Altitude of holotype and one paratype, 1.0 and 1.0 mm.; width, 2.8 and 2.8 mm.; diameter of umbilicus, 0.8 and 0.8 mm.; number of whorls, 2¼ and 2¾.

Holotype: U S. Nat. Mus. 559966; paratypes: U. S. Nat. Mus. 559967.

VORTICIFEX TRYONI Meek

Plate 76, figures 15a, b

Carinifex (*Vorticifex*) *tryoni* MEEK, 1870, Acad. Nat. Sci. Philadelphia Proc., vol. 22, p. 59; 1877, U. S. Geol. Expl. 40th Parallel vol. 4, pt. 1, p. 188, pl. 17, figs. 10–10b.

This species is represented here by numerous examples of various developmental stages. One specimen measures 7.2 mm. in altitude of shell, 12.6 mm. in width; 5.0 mm.

in height of aperture, and 6.0 mm. in its width; and has about four whorls. The spire is somewhat variable in elevation, early whorls of some individuals are coiled on almost the same level as the last whorl, while those of others are somewhat depressed below the top of the body whorl, which produces a concave aspect. The early whorls seem to be carinated or acutely angulated above the periphery or along its shoulder. The carina or angulation in most cases has been covered by the coiling of the succeeding whorl, but it is well shown on the young shells.

The young shell of this species is readily differentiated from that of others by its rapid increase in height as well as in width of the last whorl, which in general is obtusely to strongly angulated along its shoulder. The umbilicus is narrow but open.

Figured specimen: U. S. Nat. Mus. 559968.

VORTICIFEX TRYONI CONCAVA Meek
Plate 76, figures 16a, b

Carinifex (*Vorticifex*) *tryoni* var. *concava* MEEK, 1870, Acad. Nat. Sci. Philadelphia Proc., vol. 22, p. 59; 1877, U. S. Geol. Expl. 40th Parallel, vol. 4, pt 1, p. 189, pl. 17, fig. 10c.

There are four examples which are characteristically identical with Meek's figure for his variety. The shell is of small size, about 1.2 in altitude of shell, 2.6 in its width, and has about 2½ whorls with noticeably strong ribs over its exposed surface. It differs from species of *Armiger* by the higher altitude of the shell, smaller number of whorls and narrower umbilicus.

Figure specimen: U. S. Nat. Mus. 559969.

CARINIFEX BREVISPIRA Yen, n. sp.
Plate 76, figures 18a, b

Shell small ultradextral, moderately thick, having a sunken summit, depressed or nearly flattened spire and moderately descending body whorl. The whorls are strongly angulated on the shoulder, increasing rapidly in size; they are coiled normally below the shoulder and separated by an incised suture. The body whorl bears two strong carinae, one on the shoulder or slightly above the periphery and another around the umbilicus. The periphery is broad and obtusely angulated and rapidly reduced below. The aperture is subquadrangular in outline, having its peristome thin and continuous; parietal wall barely attached to the penultimate whorl.

Altitude of holotype and one paratype, 2.5 and 1.5 mm.; width, 4.1 and 2.5 mm.; height of aperture, 2.0 and 1.0 mm.; width of aperture, 1.5 and 0.7 mm.; diameter of umbilicus, 2.0 and 1.0 mm.; number of whorls, 4 and 2½.

This species is characterized by its small size, nearly flattened spire, and low altitude of the shell, which seem to separate the present species from other known *Carinifex* reported from Pliocene to Recent deposits.

The younger specimens are readily separated from those of *Vorticifex tryoni* Meek by the presence of two prominent spiral carinae on the last whorl, and by having more gradually increasing whorls.

Holotype: U. S. Nat. Mus. 559970; paratypes: U. S. Nat. Mus. 559971.

PLANORBIFEX IDAHOENSIS Yen, n. sp.
Plate 76, figures 17a, b

Shell small, ultradextral, having a slightly sunken summit, nearly flattened spire, and rapidly enlarged body whorl. The whorls are scarcely convex, increasing rapidly in size, and bearing distinct lines of growth. The exposed surface of the early whorls is distinctly carinated, and the carination is clearly traceable along the incised suture. The last whorl is carinated in addition below the periphery and around the umbilicus. The aperture is transverse-ovate in outline, having its peristome thin and continuous with its parietal wall barely attached to the penultimate whorl.

Altitude of holotype and two paratypes: 1.7, 1.6, and 1.5 mm.; width, 3.5, 3.1, and 2.8 mm.; height of aperture, 1.0, 0.8, and defective; width of aperture, 1.2, 1.0, and defective; diameter of umbilicus, 0.9, 0.8, and defective; number of whorls, 3⅛, 3, and 3.

The carinated whorls and rather narrow umbilicus of this species suggest features of *Planorbifex* Pilsbry, though it differs from *P. vanvlecki* (Arnold) by its smaller size, more prominently tricarinate whorls, and generally flattened spire.

The young specimens of this species may

often be confused with those of the preceding two species, although they are generically different. By the lower altitude of the shell in proportion to its width, the prominent carinate whorls, and the wider umbilicus, the young of *P. idahoensis* are readily separated from those of *Vorticifex tyroni*. On the other hand, they are readily distinguished from the young of *Carinifex brevispira* by their lower altitude, less strongly carinated whorls, and narrower umbilicus.

Holotype: U. S. Nat. Mus. 559972; paratypes: U. S. Nat. Mus. 559973.

PAPYROTHECA IDAHOENSIS Yen, n. sp.
Plate 76, figure 19

Shell of minute size, apparently sinistral, slender and subcylindric in outline. The apex is bluntly pointed, and the whorls are scarcely convex, increasing rapidly in size, the first one to one and one-half whorls are laterally compressed, more or less coiled, while the following one is only slightly curved. The whorl surface appears to be smooth, distinctly but not acutely angulated along the suture. The suture is narrowly but not deeply canaliculate. Aperture not well preserved, appearing to be narrowly oblong in form, having its peristome apparently thin and continuous, forming an acute angle at its posterior end.

Altitude of holotype and one paratype, 3.0+ and 3.0 mm.; width of shell, 1.2 and 1.4 mm.; number of whorls, 2½ and 2 mm.

This characteristic and interesting species resembles *Papyrotheca pseudogyra* Brusina and related species, which were described from Pontian beds exposed near Ripanj in Serbia, but it differs by its more slender outline, by having one to one and one-half whorls coiled, and one more narrowly canaliculate suture, which is defined by an angulation of the whorl.

When Brusina in 1893 (pp. 160–161) described for the first time *Papyrotheca* and its three species, he evidently intended to assign his new genus to Lymnaeidae. But Wenz in 1923 included this genus in Succineidae, members of which are of amphibious and terrestrial habitat.

Judging by its slender outline, bluntly pointed apex, brief stage of coiling in its early whorls and canaliculate suture, the genus resembles *Camptoceras* Benson, a genus described from living species distributed in Eastern Asia, with which *Papyrotheca* may be possibly related. *Camptoceras* is generally considered to be a genus of Bulininae in Planorbidae or Bulinidae.

Holotype: U. S. Nat. Mus. 559974; paratypes: U. S. Nat. Mus. 559975.

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EOCENE NONMARINE GASTROPODS FROM HOT SPRING COUNTY, WYOMING

TENG-CHIEN YEN[1]
Philadelphia, Pa.

THE MATERIAL dealt with in this paper was collected by Dr. J. D. Love, of the United States Geological Survey, and the members of his party in the summer of 1944 at the northeastern end of the Lysite Mountain in sec. 36, T. 42 N., R. 90 W., Hot Spring County, Wyoming. The specimens are imbedded in marly limestone of fine texture and light greenish gray color.

The stratigraphy of the fossil site has been well treated by Mr. H. A. Tourtelot in his forthcoming report on the Tertiary stratigraphy in the northeastern part of the Wind River Basin, Wyoming. The entire sequence is over 600 feet in thickness, and the freshwater mollusks described in the present paper were obtained from the uppermost part of this sequence.

The collection includes 13 species of gastropods, representing eight genera in six families. Two of the species are undeterminable on account of imperfect preservation. Apparently the molluscan fauna of the deposit is only partially represented; however, these new records in distribution are undoubtedly interesting and useful from the stratigraphic as well as the paleontologic point of view.

A few generic names, such as *Australorbis* Pilsbry, *Anisus* Studer, and *Menetus* H. and A. Adams, are here adopted purely on morphological grounds. The phylogenetic relationship of the species of the present collection assigned to these genera is by no means established, though it is possible that they belong to groups closely related to the genera to which they are here provisionally assigned.

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Almost all the forms here recorded are known species; very little doubt attaches to the specific identifications or the nearest affinities of the species. They are therefore a valuable aid in age determination of the deposit in which they are preserved. The figured specimens are preserved in United States National Museum.

COMPOSITION OF THE FAUNA AND AGE OF THE DEPOSIT

These beds yield the following species of gastropods:

Aminicolidae.
Charydrobia, species undetermined
Lymnaeidae.
Lymnaea cf. *vetusta* Meek
Lymnaea similis Meek
Physidae.
Physa cf. *bridgerensis* Meek
Physa cf. *pleromatis* White
Physa, species undetermined
Planorbidae.
Australorbis spectabilis (Meek)
Australorbis utahensis (Meek)
Anisus cirrus (White)
Menetus cf. *vetulus* (Meek and Hayden)
Helminthoglyptidae.
Glypterpes veternus (Meek and Hayden)
Pupillidae.
Vertigo arenula (White)
Vertigo atavuncula (White)

However, the species at three different levels form slightly different combinations. It may be noted that a bed 30 feet from top of the exposure yields the following forms:

Charydrobia sp. undet.
Physa sp. undet.
Australorbis spectabilis (Meek)
Australorbis utahensis (Meek)
Anisus cirrus (White)
Menetus cf. *vetulus* (Meek and Hayden)
Glypterpes veternus (Meek and Hayden)

Forty feet from the top of the exposure, the following species were obtained:

Lymnaea cf. *vetusta* Meek

Lymnaea similis Meek
Physa cf. *bridgerensis* Meek
Physa cf. *pleromatis* Meek
Australorbis spectabilis (Meek)
Anisus cirrus (White)
Menetus cf. *vetulus* (Meek and Hayden)
Vertigo arenula (White)
Vertigo atavuncula (White)

A bed about 5 feet below the level or 45 feet from the top yields numerous examples of *Australorbis spectabilis* (Meek) only.

With the exception of the *Charydrobia*, all the forms contained in the collection belong to the Pulmonata. The fresh-water snails were dwellers among aquatic vegetation, while the small number of land species is evidently an accidental admixture. The molluscan species permit the inference that the deposit was probably formed by a sizable but shallow body of still water, and this suggestion is quite consistent with the uniform lithology of the fossil bed. The helicoid species of land snail suggests possibly that this extinct body of water was surrounded by or close to a forested land.

The presence of the polygyral species of large planorbids suggests a tropical or subtropical climate in the area, as they morphologically resemble species in the Recent fauna that are now more or less restricted to the neotropical zone.

Seven of the eight fresh-water species in the collection that have been identified or brought into comparison have been previously reported from the Eocene. *Lymnaea similis* and *L. vetusta* are from the Bridger formation; *Physa bridgerensis* and *P. pleromatis* are from the Bridger and Wasatch formations, respectively; the large planorbids, *Australorbis spectabilis* and *A. utahensis*, are from the Bridger and equivalent; *Anisus cirrus* is from the Green River formation. The terrestrial forms, *Glypterpes veternus*, *Vertigo arenula*, and *V. atavuncula*, are generally considered to be Eocene species. *Menetus vetulus* (Meek and Hayden) has been known only from the White River Oligocene in South Dakota, and to this species one of the forms here seems to be related. However, such a carinated form of "*Menetus*" could possibly also be found in an earlier formation.

As far as the available findings indicate, the deposit seems to be more reasonably assigned to Eocene and is possibly equivalent to the Bridger formation. This viewpoint may be further supported by the fact that large planorbids and carinated species of "*Menetus*," together with high-spired *Lymnaea*, were also reported from the Lutetian near Longpont, Aisne, France, and that similar planorbids and "*Menetus*," together with sizable *Physa*, were recorded by Odhner from the Eocene marly limestone near Yuanchu, Shansi Province, China. Nevertheless, another possibility must be considered, that these fossil snails might be the remains of an Eocene fauna that had persisted in the area to a later age, namely, Oligocene. This suggestion the evidence seems to deny. First of all, the survival of a whole group of species together from one age to another is less likely than their reference to an earlier age. In other words, the length of time in this case seems to be a more important factor than the limit of space. Moreover, only one of the species in the present assemblage has been reported to have relatives in the generally accepted Oligocene. Taken all together it seems that in the present state of our knowledge the suggestion of a younger age for this deposit is without substantial support.

SYSTEMATIC ACCOUNT

Family AMNICOLIDAE

CHARYDROBIA, sp. undet.

A single specimen seems to belong to this genus, forms of which have been recorded from the Lower and Upper Cretaceous formations in North America as well as in Europe. A number of genera of the Amnicolidae (=Hydrobiidae), such as *Hydrobia* (s.s.), *Bythinella* (s.s.), and *Amnicola* are well represented from Cretaceous to Recent times. *Charydrobia* may prove to be another long-ranging genus in the family. According to Wenz, *Charydrobia* Stache is a synonym of *Pseudamnicola* Paulucci.

Specific identification of this form remains uncertain on account of imperfect preservation. This single example measures 4.5 mm. in altitude of shell, 2.8 mm. in its width, and has about 5 whorls.

Family LYMNAEIDAE

LYMNAEA cf. L. VETUSTA Meek

Figure 1

Limnaea vetusta MEEK, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 314.—WHITE, 1883, U. S. Geol. Survey Ann. Rept., 3 p. 445, pl. 29, figs. 22, 23.

A single specimen, with the last one and one-half whorls preserved, seems to approach this species in size and general outline. However, its specific identity will have to be confirmed by more perfectly preserved specimens.

Figured specimen: U.S.N.M. 559930.

LYMNAEA SIMILIS Meek

Figure 2

Limnaea similis MEEK, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 314, 1860.—WHITE, 1883, U. S. Geol. Survey Ann. Rept. 3, p. 445, pl. 29, figs. 20, 21.

A single specimen seems to be identical with this species, which was described from the Bridger formation in southwestern Wyoming. The whorls are slightly more convex than those of the type. It measures 6.2 mm. in altitude, 3.0 mm. in width, 3.0 mm. in height of aperture, 1.6 mm. in width of aperture. It has four and one-third whorls.

This and the preceding species were assigned to the genus *Galba* by F. C. Baker in 1911, which assignment was followed by Wenz in 1923. However, I have not observed the characteristically dilated columella and parietal margins of *Galba* in the type figures or the specimens contained in this lot. It seems to be therefore more advisable to leave them in *Lymnaea*, s.l.

Plesiotype: U.S.N.M. 559931.

Family PHYSIDAE

PHYSA cf. P. BRIDGERENSIS Meek

Figure 3

Physa bridgerensis MEEK, 1872, U. S. Geol. and Geog. Survey Terr. Ann. Rept. 6, p. 516.—WHITE, 1883, U. S. Geol. Survey Ann. Rept. 3, p. 450, pl. 30, figs. 9, 10.

Two specimens imperfectly preserved seem to approach this species in outline. However, they are much smaller. The larger one measures 15.5 mm. in altitude, 8.2 mm. in width, and has 5 whorls.

It differs from *Physa secalina* Evans and Shumard, described from Oligocene beds of South Dakota, in its higher spire and stouter outline.

Figured specimen: U.S.N.M. 559932.

PHYSA cf. P. PLEROMATIS White

Figure 4

Physa pleromatis WHITE, 1877, U. S. Geol. Surveys W. 100th Mer. Rept., vol. 4, pt. 1, p. 211, pl. 21, fig. 1.

The present lot contains two examples which seem to be related to, if not identical with, this species. The larger example measures 23.0 mm. in altitude, 15.0 mm. in width, and has about five whorls (apical part slightly injured). They differ from *Physa* cf. *P. bridgerensis*, noted above, in their larger size, more robust outline, and shorter spire.

Figured specimen: U.S.N.M. 559933.

PHYSA, sp. undet.

A single imperfect specimen consists of about four scarcely convex whorls, with spire about one-third of the entire shell altitude. Part of the body whorl is not preserved, but the back view of the specimen shows that the shell has an elongate outline and a high spire and resembles *Physa bridgerensis*, though of much smaller size.

Family PLANORBIDAE

AUSTRALORBIS SPECTABILIS (Meek)

Figures 5a, b

Planorbis spectabilis MEEK, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 314, 1860.—WHITE, 1883, U. S. Geol. Survey Ann. Rept. 3, p. 447, pl. 29, figs. 4–6 (as a variety of *Planorbis utahensis*).

The present lot contains several specimens, including a few younger individuals, that are identical with this characteristic species. One of the well-preserved examples measures 12.0 mm. in altitude, 39.5 mm. in diameter, and has six whorls; another one is 10.2 mm. in altitude, 31.6 mm. in diameter and has five and three-fourths whorls.

The shell features of this species resemble those of some living species of *Australorbis* Pilsbry now distributed over Central and South America. However, on account of the long range in time, their relationship cannot be positively established at present.

Plesiotype: U.S.N.M. 559934.

AUSTRALORBIS UTAHENSIS (Meek)
Figures 6a, b

Planorbis utahensis MEEK, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 314.—WHITE, 1883, U. S. Geol. Survey Ann. Rept. 3, p. 447, pl. 29, figs. 1–3, 1883.

A single specimen has its shell flattened by distortion, but it is still identifiable on comparison with the type specimen contained in the collection of the United States National Museum. It differs from *A. spectabilis* (Meek) by its angulated periphery and wider body whorl.

The large size and polygyral volutions of this and the preceding species remind one of "*Planorbis*" *pseudammonius* Schlotheim and a few of its allied forms that were described from the Eocene beds of France and western Germany. The typical form of "*P.*" *pseudammonius* is considered to be one of the leading index fossils of the limnic deposits of the Lutetian formation in Europe. "*P.*" *spectabilis* has been reported, as the previous records show, only from the Bridger formation or deposits of equivalent age in North America.

Plesiotype: U.S.N.M. 559935.

ANISUS CIRRUS (White)
Figures 7a, b

Planorbis cirrus WHITE, 1877 (1879), U. S. Geol. and Geog. Survey Terr. Ann. Rept. 11, p. 251; 1878 (1883), *idem*, Ann. Rept. 12, p. 44, pl. 19, fig. 5.

Several examples, including young individuals, are identical with *A. cirrus* White. One of the well-preserved specimens measures 2.5 mm. in altitude, 10.0 mm. in diameter, and has about eight whorls. This size is slightly larger than that of the type.

Wenz in 1923 assigned this species to *Paraspira* Dall, 1905, which according to Pilsbry (1934) and F. C. Baker (1944) is a synonym of *Anisus* Studer, 1820. The shell features of "*Planorbis*" *cirrus* resemble those of *Anisus*, though no species of the genus has been previously known earlier than Tortonian Miocene.

Plesiotype: U.S.N.M. 559936.

MENETUS cf. M. VETULUS
(Meek and Hayden)
Figures 8a, b

Planorbis vetulus MEEK AND HAYDEN, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 175.—WHITE, 1883, U. S. Geol. Survey Ann. Rept. 3, p. 448, pl. 32, figs. 16–18 (as *Planorbis vetustus*).

There are three examples contained in the collection. The matured example measures 2.0 mm. in altitude, 6.2 mm. in diameter, and has about five and three-fourths whorls. It approaches the size and general outline of *Planorbis vetulus*, which was described from the White River formation, of Oligocene age, of South Dakota. However, it differs in having more whorls and a wider body whorl.

Figured specimen: U.S.N.M. 559937.

Family HELMINTHOGLYPTIDAE
GLYPTERPES VETERNUS (Meek and Hayden)
Figure 9

Helix veternus MEEK AND HAYDEN, 1861, Acad. Nat. Sci. Philadelphia Proc., vol. 13, p. 447.—WHITE, 1883, U. S. Geol. Survey Ann. Rept. 3, p. 454, pl. 30, figs. 4, 5.

A single specimen with its last two whorls preserved seems to be identical with *Helix veternus*. It measures 32.0 mm. in altitude, 35.5 mm. in width, 24.6 mm. in height of aperture, 21.5 mm. in width of aperture. The outer lip is slightly reflected at the basal part, the parietal callus is thin but well defined, and the columellar margin is well thickened and reflected so as to cover the umbilicus completely.

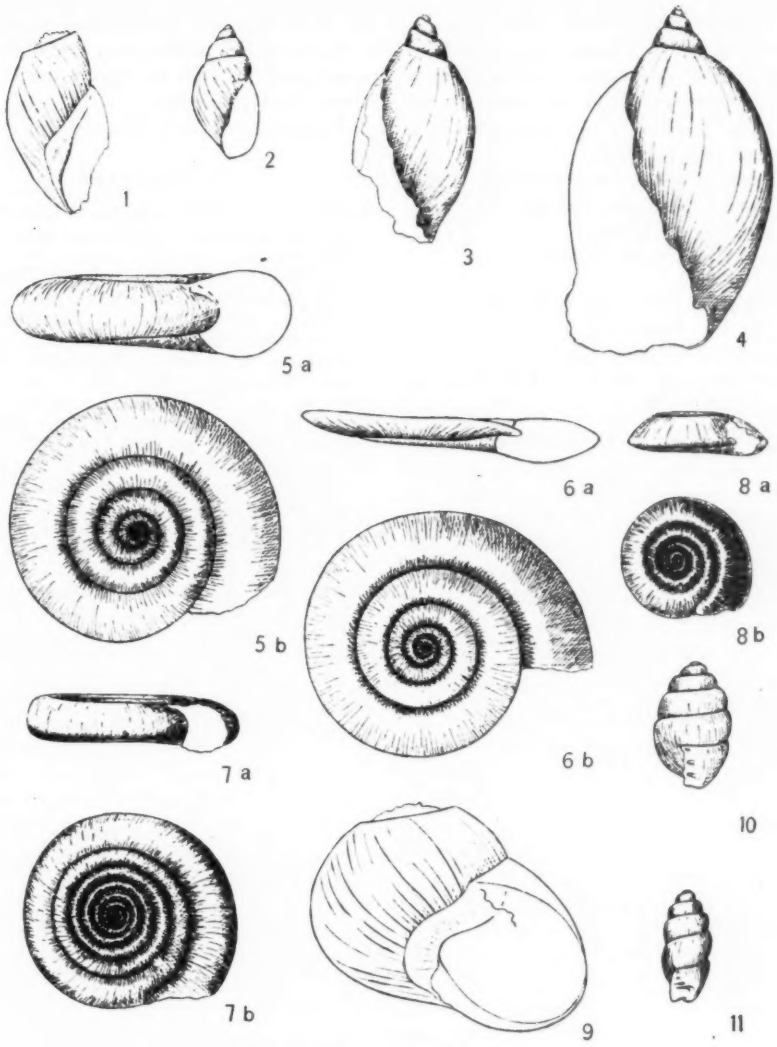
The advantage of recognizing *Glypterpes* Pilsbry, 1892, is to establish a more precise conception of this species, which existed in Eocene time and probably has little to do with the genus *Helix*. Opinion may differ in choosing between *Glypterpes* and *Helminthoglypta* for the genus of this species, but not between *Glypterpes* and *Helix*.

Plesiotype: U.S.N.M. 559938.

Family PUPILLIDAE
VERTIGO ARENULA (White)
Figure 10

Pupa arenula WHITE, *in* POWELL, 1876, Rept. geology Uinta Mountains, p. 105; 1878 (1883), U. S. Geol. and Geog. Survey Terr. Ann Rept., 12, pt. 1, p. 46, pl. 19, fig. 8.

Several specimens approach this species in size and form. The shell is narrowly perforated and distinctly marked by two strong crests on the outer wall of the peristomal margin, which generally indicate presence of two well-developed teeth on its inner wall.



EXPLANATION OF FIGURES 1–11

FIGS. *1*—*Lymnaea* cf. *L. vetusta* Meek, ×4. (p. 497)
2—*Lymnaea similis* Meek, ×6. (p. 497)
3—*Physa* cf. *P. bridgerensis* Meek, ×4. (p. 497)
4—*Physa* cf. *P. pleromatis* White, ×4. (p. 497)
5a, b—*Australorbis spectabilis* (Meek), ×2. (p. 497)
6a, b—*Australorbis utahensis* (Meek), ×2. (p. 498)
7a, b—*Anisus cirrus* (White), ×6. (p. 498)
8a, b—*Menetus* cf. *M. vetulus* (Meek and Hayden), ×6. (p. 498)
9—*Glyptcrpes veternus* (Meek and Hayden), ×2. (p. 498)
10—*Vertigo arenula* (White), ×14. (p. 498)
11—*Vertigo atavuncula* (White), ×14. (p. 500)

These characters were not detailed in White's original description. However, he mentioned that the "last volution contracted near the aperture," and this contraction may indicate the presence of the crests, which are usually not well seen on a poorly preserved specimen.

One of the well-preserved examples measures 2.5 mm. in altitude, 1.5 mm. in width, and has about five whorls.

Plesiotype: U.S.N.M. 559939.

VERTIGO ATAVUNCULA (White)
Figure 11

Pupa atavuncula WHITE, 1878 (1883), U. S. Geol. and Geog. Survey Terr. Ann Rept. 12, pt. 1, p. 46, pl. 19, fig. 9.

Several examples in this collection seem to agree in size and outline with the species. They bear two weak but distinct crests on the external side of the peristomal margin. White's description was based on a poorly preserved example that has its aperture injured. One of the better-preserved specimens in this lot measures 2.1 mm. in altitude, 1.0 mm. in width, and has 5 whorls.

RECEIVED FEBRUARY 19, 1946.

It differs from the preceding species by its more elongate outline and weaker crests.

Both species in the present collection were associated, as were the types, with species of *Physa* and *Planorbis*.

Plesiotype: U.S.N.M. 559940.

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JOURNAL OF PALEONTOLOGY, VOL. 20, NO. 5, PP. 501–504, 4 TEXT FIGS., SEPTEMBER 1946

ORIENTATION OF THE CRYSTAL UNITS OF CONODONTS

WILBERT H. HASS AND MARIE L. LINDBERG
Geological Survey, U. S. Department of the Interior, Washington, D. C.

ABSTRACT—Petrographic and spectrographic observations on conodonts from several formations of Ordovician, Mississippian, and Pennsylvanian age are recorded and interpreted. The conclusions are: (a) conodonts are composed of fluorine-bearing dahllite, a member of the dahllite-francolite isomorphous series of apatite minerals; (b) each lamella of a conodont is composed of innumerable dahllite crystals; and (c) the *c*-axis of each dahllite crystal is invariably oriented in the direction in which the main ontogenetic growth occurred at the place in the lamella where the crystal is located.

INTRODUCTION

THIS PAPER treats of some petrographic and spectrographic observations on conodonts. It presents corroborative evidence on the composition of conodonts, records the optical properties of the crystals composing conodonts, and establishes the orientation of the crystal units in each lamella of a conodont. The petrographic observations for the paper were made on numerous specimens from the Ordovician, Mississippian, and Pennsylvanian formations listed in table 1. Spectrographic analyses were made on samples from four of these collections.

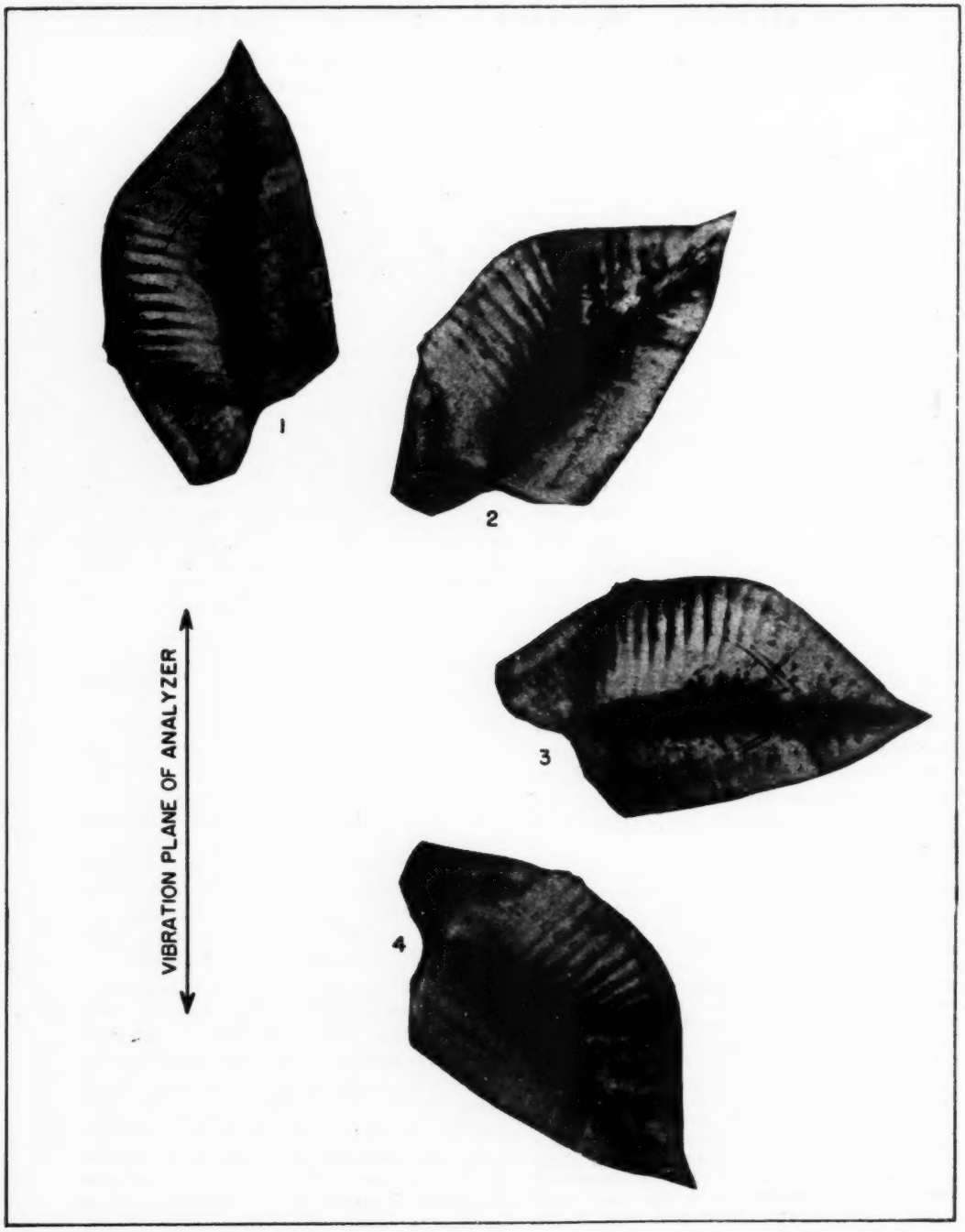
The paper is a sequel to one (Hass, 1941) that dealt with a description and interpretation of the histologic features of conodonts as seen in thin sections. The following summation of the microstructures is taken from that paper:

> [All] distacodid, compound, and platelike conodonts are characterized by a laminated structure open toward the aboral side and built up about the apex of the pulp cavity by an accretionary process. The lamellae present in any conodont can be thought of as representing distinct growth stages in the ontogeny of that specimen. The first few growth stages of all conodonts were quite similar, their lamellae being not unlike a cone-in-cone structure; but after this early stage each species began to bear out its own ontogenetic pattern by concentrating its main growth along definite lines. In the distacodids, growth was along a single axis, whereas in the compound and platelike forms it took place simultaneously in several directions and along many axes . . . the result of this directional growth in any specimen being that each additional lamella assumed more and more of the characteristic shape of the mature individual; or, stated somewhat differently, that a conodont species is a variable entity, the external forms of the specimens belonging to any one species being directly dependent upon the stages of ontogenetic development that they reached. In any conodont, the lamellae are extended along the lines of most active growth and are separated from one another by interlamellar areas. These areas, which are hollow or but slightly filled with structural material, are often, especially in the earlier stages of growth, more than 20 times as wide as the lamellae that they separate; but in the directions of less active growth, as well as in the later stages of growth along any one axis, the lamellae are arranged more compactly, the interareas there being narrow or missing.

COMPOSITION OF CONODONTS

Ellison (1944) has assembled chemical and physical data on conodonts from which he has concluded that the mineral matter of conodonts is similar in composition to the minerals of the apatite group. Stauffer (1938), basing his conclusion on X-ray analyses, also noted this affinity and stated that conodonts are composed of collophane. Duncan McConnell, who supplied Stauffer with the X-ray analyses, wrote in 1940 (Ellison, 1944) that "some conodonts are probably dahllite, others francolite, and some probably lewistonite or dehrnite."

For the present paper, spectrographic analyses were made on four samples from the localities starred in table 1 and their spectrograms were compared with that of a chemically analyzed apatite crystal (USGS chem. lab. record no. D-403) from Gunnison County, Colorado. To all intents and purposes the composition of the four samples is the same, for all contain about 1 per cent of fluorine in addition to major proportions of calcium and phosphorous. Conodonts, moreover, effervesce in warm hydrochloric acid, and this fact, together with those ob-



FIGS. 1–4—Extinction at 45° intervals in the platforms of *Siphonodella duplicata* (Branson & Mehl). USGS Carboniferous figured specimen no. 7512, ×50 ±.

tained through spectrographic and optical means, indicates that conodonts are composed of a mineral of the apatite group belonging to the dahllite-francolite isomorphous series. Inasmuch as they contain about 1 per cent of fluorine and therefore lie closer to the dahllite end of the isomorphous series, conodonts are considered to be composed of fluorine-bearing dahllite.

TABLE 1. OPTICAL DATA ON CONODONTS
(Measurements by Marie L. Lindberg)

	Maximum observed range of indices of refraction		Majority of specimens with indices of refraction between
	Epsilon	Omega	
Pennsylvanian			
Scranton shale, Emporia, Kansas (8411)....	1.601–1.614	1.605–1.618	1.613–1.618
*Des Moines group, St. Louis outlier, St. Louis County, Missouri (6777).....	1.600–1.615	1.604–1.618	1.613–1.618
Mississippian			
Barnett shale, San Saba County, Texas (9028).....	1.601–1.621	1.605–1.625	1.608–1.618
Chappel formation, San Saba County, Texas (9013).....	1.601–1.618	1.605–1.622	1.613–1.618
Chappel formation, Burnet County, Texas (9055).....	1.600–1.618	1.603–1.622	1.608–1.618
*Chappel formation, Burnet County, Texas (9048).....	1.595–1.614	1.600–1.618	1.601–1.613
Welden limestone, Pontotoc County, Oklahoma (6604c).....	1.600–1.614	1.604–1.618	1.608–1.618
*Welden limestone, Pontotoc County, Oklalahoma (20-7).....	1.604–1.616	1.608–1.620	1.608–1.613
Ordovician			
*Cincinnatian, near Lexington, Kentucky..	1.608–1.622	1.612–1.625	1.613–1.618
Plattin limestone, near St. Louis, Missouri..	1.613	1.617	(1 specimen)

* Spectrographic analyses made on samples from these localities.

OPTICAL PROPERTIES OF CONODONTS

Indices of refraction.—Indices of refraction of the crystals composing conodonts were determined on numerous specimens from the collections listed in table 1. The results, which record a wider range of indices than those given by Ellison in 1944, indicate that the indices of refraction of the crystals—regardless of the age or locality of the fossils—are within the limits of variation of the indices of dahllite. The results are assembled in table 1.

As recorded in table 1, the maximum observed range for epsilon is 1.595 to 1.622 and for omega, 1.600 to 1.625 with the majority of the conodont grains having indices of refraction that fall between 1.601 and 1.618. The birefringence is low, being $0.004 \pm .001$ for all specimens. It was observed that each lamella of a conodont is composed of innumerable dahllite crystals; hence, the fossils were crushed so finely that each of the resulting grains extinguished as a unit.

Orientation of the crystal units.—In dahllite, a uniaxial mineral, the optic and the crystallographic axes coincide; and as the dahllite crystals in a conodont are in extinction only when the growth axis of which they are a part is alined with the vibration plane of the analyzer or the polarizer, it follows that the crystal units in each lamella of a conodont are oriented in conformity with the direction in which the conodont grew. The wave of extinction that moves through a conodont as the stage of the microscope is rotated is suggested by the four figures of the platforms of *Siphonodella duplicata* (Branson & Mehl). Figures 1 and 3 are similar, for they record the two extinction positions of the same group of crystals; figures 2 and 4 resemble each other for the same reason. In

FIGS. 1–4.—Extinction at 45° intervals in the platforms of *Siphonodella duplicata* (Branson & Mehl). USGS Carboniferous figured specimen no. 7512, ×50±.

all four figures the darkened area along the carina is caused partly by extinction and partly by an excessive absorption of light.

The retardation of light by a conodont specimen is slight. Most specimens appear gray or yellow between crossed nicols and only a few show a spot of first-order red. The retarding effect of the crystal units of a conodont on the gypsum plate is such that the predominant color resulting from subtraction is first-order yellow and the colors resulting from addition are first-order purple and second-order blue and green. Optically, dahllite is negative, and in conodonts the feature of subtraction results only if a direction of ontogenetic growth is alined with the slow vibration plane of the gypsum plate. Hence, it follows that the *c*-axis of each dahllite crystal is invariably oriented in the direction in which the main ontogenetic growth occurred at the place in the lamella where the crystal is located. The color seen at any spot on a conodont is produced by the mass effect of a number of superimposed crystals. These crystals are not in exact alinement, but, as their birefringence is low, the resultant color approximates that which would be seen if the crystal units were actually parallel.

ACKNOWLEDGEMENTS

The writers wish to thank Mr. K. J. Murata for supplying the spectrographic data for this paper and Mr. L. G. Henbest for making the photographs including some in color that record the retarding effect of the crystal units of a conodont on the gypsum plate.

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A LOWER CRETACEOUS FAUNA IN THE NORTHWEST BASIN OF WESTERN AUSTRALIA

IRENE CRESPIN
Mineral Resources Survey, Canberra, Australia

INTRODUCTION

EXTENSIVE deposits of Cretaceous age are developed in the northwest basin of Western Australia. The main exposures of Upper Cretaceous rocks occur along the eastern scarp of the Cardabia-Giralia Range, and sediments of that age have been proved by boring to exist over a larger area. Beds referred to the Lower Cretaceous have an even greater extent and, according to Raggatt (1936), outcrop over a distance of nearly 200 miles from Minderoo Station on the Ashburton River south to the Gascoyne River. Examination of samples from bores in the area indicates that the Lower Cretaceous occurs at considerable depths.

In 1935, Condit and Rudd instituted the name "Winning formation (or series)" for the group of white, yellowish and pinkish radiolarian cherts, white to grey siltstone, dark-grey gypseous shales and mudstones, and glauconitic sandstone, developed at Winning Pool on Winning Station, which is situated between Carnarvon and Onslow (fig. 1).

The Winning formation contains an assemblage of Foraminifera and Radiolaria. This association is a characteristic one in the Lower Cretaceous deposits of Australia (Crespin, 1945). It is found in many of the samples examined from bores in the great artesian basin in northern New South Wales and South Australia. The only abundant large fossil in the Winning formation is the belemnite *Dimitobelus diptycha* (McCoy). Whitehouse (1926) suggests that the beds may be equivalent in age to the Tambo series in Queensland, which is referred to the Albian. Chapman considered the Winning beds to be upper Albian and equivalents of the radiolarian rocks described by Hinde (1893) from Fanny Bay, Darwin, Northern Territory.

The material upon which this paper is based was collected by Dr. Washington Gray formerly of the Commonwealth Oil Refineries Pty., Ltd., and by Messrs. Raggatt, Rudd and Condit, formerly of Oil Search, Ltd., during their investigations in the search for oil in the northwest basin. The samples were collected from outcrops, from bores, and from dumps adjacent to bore holes. These bores were drilled to obtain supplies of artesian water, which occur chiefly at the base of the Cretaceous system.

LOCALITIES FROM WHICH RADIOLARIA AND FORAMINIFERA HAVE BEEN DETERMINED

Radiolarian Cherts and Siltstones

Hill A45, 11 miles southeast of Winning Pool Station.
Scarp, 1 mile north of Winning Pool post office, on Giralia Track.
Winning Station Bluff, 7 miles northwest of Winning Pool post office.
Moogooree homestead.
Hill A46, Lyndon.
Western edge of the Kennedy Range on the Hill Springs Station, about half a mile east of the track end and windmill.
Hill 1½ miles north of track towards Cardabia outcamp.
Cardabia Creek, Cardabia Station, left bank on Korojon wagon road.
Chalk Hill, Middalya Station.
Middalya Station, 2½ miles east of milepost 62 in rabbit-proof fence.
West of Murie well.
Bluff south of Wooramel River.

Shale, Mudstones, and Sandstone containing Foraminifera and Radiolaria

Winning Station.
One mile northeast from Remarkable Hill on bearing 205°.
Cardabia Creek, Cardabia Station, above cattle pool.
Windalia Hill.
Carnarvon (or Pelican Hill) bore, 10 miles north of Carnarvon, from 1105 feet down to 1286 feet.

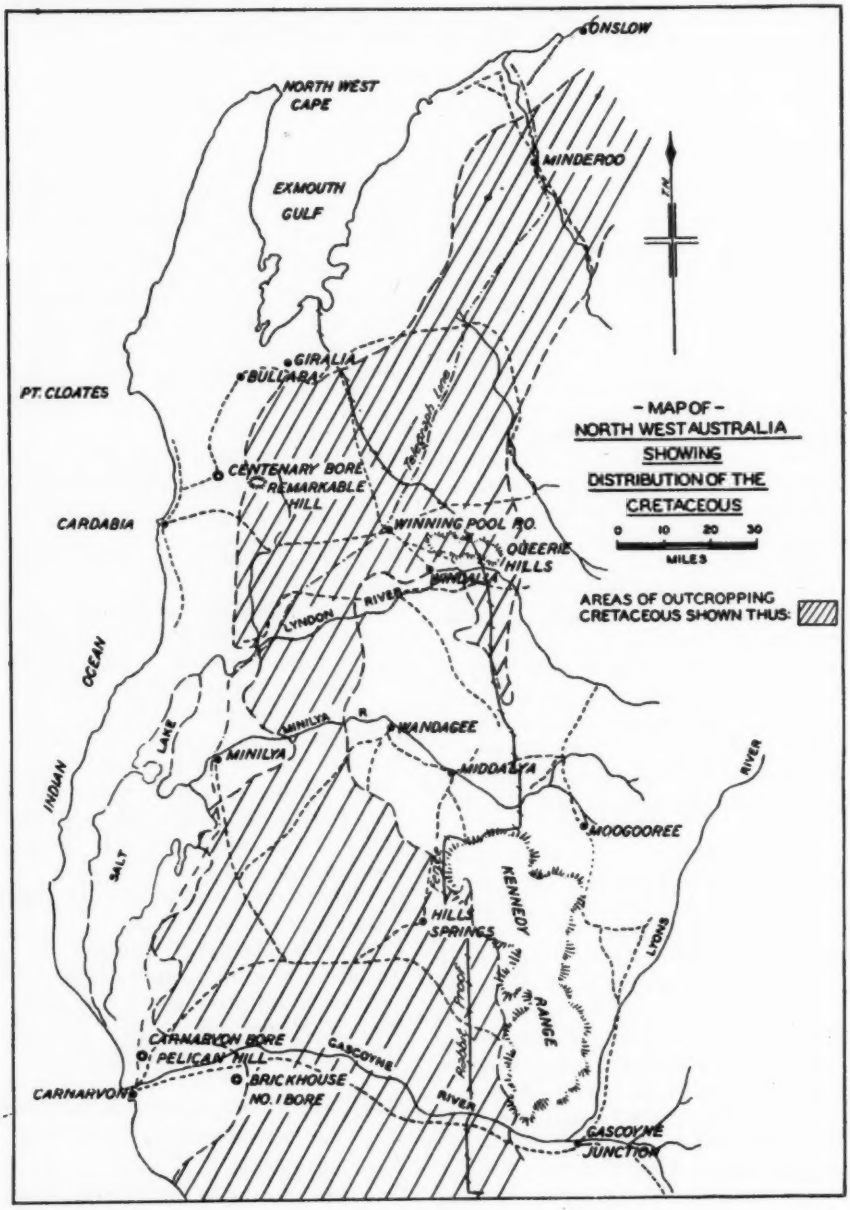

FIG. 1—Distribution of Cretaceous beds in Northwest Australia.

Brickhouse bore, 20 miles east of Carnarvon, from 1,038 feet down to 11,171 feet.
Chalk Hill, Middalya Station.

Samples from Dumps adjacent to Bores, Radiolaria Numerous

Winning Station, no. 1 successful bore, Muradich-Queerie block boundary, 0–65 feet.
Winning Station, no. 2 dud bore.
Coburn Station, no. 4 (gassy) bore.
Cardabia Station, southeast Tannawarra paddock.
Cardabia Centenary bore.
Queerie Block bore, west of Hill A45.
Bore southeast corner Chinty paddock, Minderoo.
Bore 10.5 miles southwest of Winning homestead on road to Windalia Hill.

NOTES ON THE FAUNA

Foraminifera.—Foraminifera are not common in the Lower Cretaceous beds of the northwest basin. The specimens are poorly preserved and, for the most part, only generic determinations are possible. As in the Lower Cretaceous deposits of eastern Australia (Crespin, 1944), arenaceous forms predominate. The Foraminifera occur in grey, slightly carbonaceous mudstones and shales of bore samples, where they are usually associated with well-preserved Radiolaria. Very occasionally minute tests of forms such as *Globigerina* are present in the typical cherts and siltstones of the Winning formation. The Foraminifera that have been recognized are as follows:

FORAMINIFERA

Ammodiscus cretacea (d'Orbigny)
Haplophragmoides sp.
Haplophragmoides cf. *H. chapmani* Crespin
Reophax sp.
Haplophragmium cf. *H. aequale* Roemer
Ammobaculites sp. 2
Verneuilina polystropha (Reuss)
Spiroplectammina sp.
Trochammina sp.
Lenticulina sp.
Marginulina bullata Reuss
Epistomina spinulifera (Reuss)

Radiolaria.—Radiolaria, which are exclusively marine in habitat and whose tests are siliceous in composition, occur in the Winning formation in abundance in the hard cream-colored cherts and siltstones, and in the grey slightly carbonaceous shales and mudstones from bores.

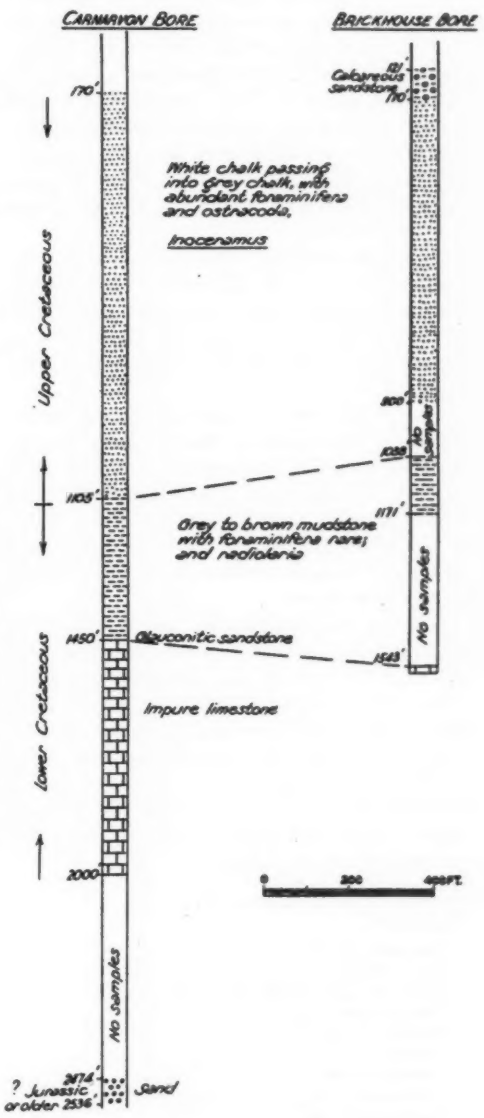

FIG. 2—Diagrammatic sections of the Carnarvon and Brickhouse bores.

Radiolaria are also found fossil in Australia in the cherty rocks of Lower Cretaceous age at Fanny Bay, Darwin, Northern

Territory (Hinde, 1893) and in the carbonaceous shales and mudstones of similar age in the great artesian basin (Crespin, 1945). They have been recorded from fine-grained carbonaceous sandstones of Permian age in deep bores in Queensland (Crespin, 1945). David (1896) described Radiolaria from the Devonian rocks of New South Wales, and David and Howchin (1896) noted their presence in Lower Cambrian rocks of South Australia. They also occur in carbonaceous rocks of Cretaceous age in the Chimbu area in New Guinea.

Recent investigation suggests that it may be possible to use Radiolaria for stratigraphic correlation because, although genera have persisted through geological ages, species are found to be restricted (Clark, 1945).

Two suborders of Radiolaria are represented in the rocks of the Winning formation, namely the Spumellaria and the Nassellaria. The discoidal spumellarians are the predominant forms. Sections of the whitish to yellowish cherts and siltstones show the rock to be crowded with tests of the globular form *Cenosphaera*.

Some of the Radiolaria from the Winning formation are referable to species described by Dr. Hinde (1893) from the material from Fanny Bay, Darwin. Other forms are new, and many of the specimens are excellently preserved in the grey mudstones and shales of the bore samples. It is not intended to describe these new species in the present paper. The Radiolaria that have been recognized are as follows:

RADIOLARIA

Spumelaria

Cenosphaera sp.
Hymeniastrum sp.
Spongodiscus expansus Hinde
Spongodiscus spp.
Amphibracium sp.
Cenellipsis sp.
Sphaerostylus sp.
Coccodiscus sp.
Staurodictya sp.
Porodiscus sp.
Spongotripus spp.
Astrophacus sp.

Nassellaria

Dictyomitra australis Hinde
D. triangularis Hinde
Lithocyclia exilis Hinde
Stylotrochus spp.
Theocapsa sp.
Tricolocapsa sp.
Stichocapsa pinguis Hinde
Stichocapsa sp.
Lithocampe fusiformis Hinde
cf. *Sethocapsa* sp.
Eucyrtidium sp.
Cyrtocapsa sp.
Rhapalosyringium sp.

NOTE ON THE STRATIGRAPHIC SEQUENCE AS SHOWN BY THE CARNARVON AND BRICKHOUSE BORES

The sections (fig. 2) of the stratigraphic sequence in these two bores are based on the examination of all available samples. The sequence is similar in both bores, the foraminiferal chalk of the Upper Cretaceous (Cardabia beds) overlying the grey foraminiferal and radiolarian mudstones of the Lower Cretaceous (Winning formation). The chalk contains a rich assemblage of Upper Cretaceous species of Foraminifera and Ostracoda together with prisms of the Cretaceous pelecypod *Inoceramus* (Crespin, 1938). In the underlying Lower Cretaceous sediments, Foraminifera are not common but Radiolaria are numerous. They are prominent in the hard dark-brown carbonaceous mudstone which underlies the friable grey mudstone.

The impure limestone underlying the radiolarian rocks apparently belongs to the Lower Cretaceous, for, at 2000 feet in the Carnarvon bore, numerous Ostracoda referable to Cretaceous species, are recorded. This limestone was represented in the lowest sample examined from the Brickhouse bore at 1543 feet. The Carnarvon bore was completed at the depth of 2536 feet in sands of uncertain age.

The map (fig. 1) shows the boundary of the Cretaceous in the northwest basin, and on it are marked the main localities referred to the Winning formation. The map is a reproduction of the one used in my earlier paper in this journal (Crespin, 1938) with the addition of further locality names. Again I express my thanks to Dr. H. G. Raggatt, Director of the Mineral Resources Survey, Canberra, for permission to use his map published in his work on the Northwest Basin in 1936.

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CHECK LIST OF THE FOSSIL FISHES OF NEW JERSEY

WILLIAM F. RAPP, JR.
Chatham, N. J.

IN NEW JERSEY two geological formations contain large numbers of fossil fishes. Many bones and teeth have been found in the marl beds of the southern part of the state. This is the better known formation, but with the passing of the marl industry, this source has been neglected. Furthermore, little attention is given the second, the Triassic shales of northern New Jersey at the present time. Unfortunately, one of the formerly most productive locations today rests at the bottom of the Boonton Reservoir.

The following paper attempts to list all species found in New Jersey. The types of the material described by Cope are located, for the most part, in the American Museum of Natural History. There, also, are most of the Triassic specimens. Leidy's are in the Academy of Natural Sciences of Philadelphia.

I wish to thank Mr. Henry W. Fowler of the Academy of Natural Sciences of Philadelphia for the help he has given me in the preparation of this paper.

Superclass PISCES
Class CHRONDROTERYGIA
Subclass PLAGIOSTOMI

Family HEXANCHIDAE

Xiphodolamia ensis Leidy (1877, p. 252). Eocene: Monmouth County; Vincentown, Burlington County (Manasquan marl); Alloway, Salem County.

Notidanion primigenium (Agassiz) (1843, p. 218). Miocene: Cumberland County. Eocene: (Shark River formation), Shark River, Monmouth County; Alloway, Salem County.

Family ISURIDAE

Carcharodon polygurus (Morton) (1834, p. 31). Eocene: Shark River, Monmouth County; Vincentown, Burlington County; Atlantic City, Atlantic County; Alloway, Salem County.

Carcharodon auriculatus (Blainville) (1816, p. 384). Eocene: Monmouth, Burlington, Gloucester, and Cumberland Counties.

Corax pristodontus Agassiz (1843, p. 224). Eocene: Monmouth and Gloucester Counties.

Isurus sillimanii Gibbes (1849, p. 268). Miocene: Cumberland County.

Isurus hastalis (Agassiz) (1843, p. 282). Eocene: Monmouth County; Vincentown, Burlington County.

Isurus desorii (Agassiz) (1843, p. 282). Eocene: Monmouth, Burlington, Gloucester, Salem and Cumberland Counties.

Lamna texana Roemer (1849, p. 419). Eocene: Gloucester, Camden, and Burlington Counties.

Lamna mudgei Cope (1875, p. 297). Eocene: New Jersey, locality not known.

Lamna appendiculata Agassiz (1843, p. 270). Eocene: Monmouth, Burlington, Camden, Salem, and Gloucester Counties.

Otodus levis Gibbes (1849, p. 268). Eocene: New Jersey, locality not known.

Otodus obliquus Agassiz (1843, p. 267). Eocene: Monmouth, Burlington, and Salem Counties.

Family CARCHARIIDAE

Carcharias cuspidatus (Agassiz) (1843, p. 290). Eocene: Monmouth, Burlington, and Salem Counties.

Carcharias elegans (Agassiz) (1843, p. 289). Eocene: Monmouth, Burlington, Gloucester, and Salem Counties.

Family EULAMIIDAE

Glyphis egertoni (Agassiz) (1843, p. 228). Eocene: Monmouth, Burlington, Gloucester, and Salem Counties.

Galeocerdo latidens Agassiz (1843, p. 231). Miocene: Alloway, Salem County.

Galeocerdo contortus Gibbes (1849, p. 193). Eocene: Monmouth, Burlington, and Salem Counties.

Galeocerdo aduncus Agassiz (1843, p. 231). Eocene: Monmouth, Burlington, and Salem Counties.

Hemipristis serra Agassiz (1843, p. 237). Eocene and Miocene: Monmouth, Burlington, Gloucester, Salem, and Cumberland Counties.

Family SPHYRNIDAE

Sphyrna gibbesii Hay (1858, p. 241). Eocene: Monmouth County.

Family PRISTIDAE

Pristis curvidens Leidy (1855, p. 414). Eocene: Monmouth and Burlington Counties.

Pristis amblodon Cope (1869, p. 312). Eocene: Monmouth County.

Family MYLIOBATIDAE

Myliobatis rugosus Leidy (1855, p. 395). Eocene: New Egypt, Ocean County.

Myliobatis rectidens Cope (1870, p. 294). Eocene: Navesink, Hornerstown formation; Harrisonville, Gloucester County.
Myliobatis pachyrhizodus Fowler (1911, p. 97). Eocene, Manasquan formation: Poplar.
Myliobatis obesus Leidy (1855, p. 396). Eocene: Burlington County.
Myliobatis magister Leidy (1877, p. 233). Eocene: Vincentown, Burlington County.
Myliobatis leidyi Hay (1899, p. 785). Eocene: Pemberton, Burlington County.
Myliobatis kummeli Fowler (1911, p. 95). Miocene, Kirkwood formation: Stow Creek, Cumberland County.
Myliobatis jugosus Leidy (1877, p. 240). Eocene: Vincentown, Burlington County.
Myliobatis glottoides Cope (1870, p. 293). Eocene, Shark River formation: Farmingdale, Monmouth County.
Myliobatis fastigiatus Leidy (1876, p. 239). Eocene: Monmouth County.
Myliobatis bisulcus Marsh (1869, p. 229). Eocene: Monmouth County.
Plinthicus stenodon Cope (1869, p. 316). Miocene (?): no given locality.
Rhinoptera dubia Leidy (1855, p. 396). Eocene: Monmouth and Burlington Counties.
Stoasodon perspicuus Leidy (1877, p. 396). Eocene: Monmouth County.

Subclass Holocephali
Family Chimaeridae

Edaphodon agassizi (Buckland) (1835, p. 206). Eocene (?): New Jersey.
Edaphodon eocaenus (Cope) (1875, pp. 285, 288). Eocene: Farmingdale, Monmouth County.
Edaphodon laterigerus (Cope) (1869, p. 243). Eocene: Hornerstown, Monmouth County.
Edaphodon mirificus Leidy (1856, p. 221). Eocene: Burlington and Monmouth Counties.
Edaphodon stenobryus (Cope) (1875, p. 285). Eocene: Hornerstown, Monmouth County.
Edaphodon tripartitus (Cope) (1875, p. 286), Eocene: Burlington and Gloucester Counties.
Bryactinus amorphus Cope (1875, p. 282). Eocene: Hornerstown, Monmouth County.
Isotaenia neocaesariensis, Cope (1875, p. 293). Eocene: Hornerstown, Monmouth County.
Leptomylus forfex Cope (1875, p. 281). Eocene: Gloucester and Monmouth Counties.
Leptomylus densus Cope (1869, p. 313). Eocene: Birmingham, Burlington County.
Leptomylus cookii Cope (1870, p. 384). Eocene: Mount Holly, Burlington County.
Sphagepoea aciculata Cope (1869, p. 241). Eocene: Birmingham, Burlington County.

Series Ichthyodorulites

Cylindracanthus ornatus Leidy (1856, p. 12). Eocene: Burlington and Monmouth Counties.
Cylindracanthus acus (Cope) (1870, p. 294). Eocene: Farmingdale, Monmouth County.

Subclass Crossopterygii
Order Actinistia
Family Coelacanthidae

Diplurus longicaudatus Newberry (1877, p. 252). Triassic, Newark group: Boonton, Morris County.
Osteopleurus milleri Shainin (1943, p. 272). Upper Triassic, Stockton formation: Granton quarry, North Bergen, Hudson County.
Osteopleurus milleri grantonensis Shainin (1943, p. 274). Upper Triassic, Stockton formation: Granton quarry, North Bergen, Hudson County.

Class Actinopteri
Superorder Ganoidei
Family Dictyopygidae

Redfieldius redfieldi (Egerton) (1847, p. 278). Triassic, Newark group: Boonton, Morris County.
Redfieldius anguilliformis (W. C. Redfield) (1841, p. 27). Triassic, Newark group: Boonton, Morris County.

Order Pycnodonti
Family Pycnodontidae

Pycnodus robustus Leidy (1857, p. 168). Eocene: location not known.
Pycnodus phaseolus Hay (1899, p. 788). Eocene: Burlington County.

Order Holostei
Family Lepidotidae

Acentrophorus chicopensis Newberry (1888, p. 69). Triassic, Newark group: Boonton, Morris County (?).
Semionotus agassizii (W. C. Redfield) (1841, p. 26). Triassic, Newark group: Boonton, Pompton, Morris County.
Semionotus alatus (Newberry) (1888, p. 37). Triassic, Newark group: Boonton, Morris County.
Semionotus beardmori (J. H. Smith) (1900, p. 502). Triassic, Newark group: Boonton, Morris County.
Semionotus braunii (Newberry) (1888, p. 43). Triassic, Weehawken, Hudson County.
Semionotus elegans (Newberry) (1888, p. 37). Triassic, Newark group: Boonton, Morris County.
Semionotus gigas (Newberry) (1888, p. 49). Triassic, Newark group: Boonton, Morris County.
Semionotus fultus (J. H. Redfield) (1837, p. 37). Triassic, group: Boonton, Morris County.
Semionotus lenticularis (Newberry) (1888, p. 39). Triassic, Newark group: Boonton, Morris County.
Semionotus lineatus (Newberry) (1888, p. 40). Triassic, Newark group: Boonton, Morris County.
Semionotus modestus (Newberry) (1888, p. 38). Triassic, Newark group: Boonton, Morris County.

Semionotus ovatus (W. C. Redfield) (1841, p. 26). Triassic, Newark group: Boonton, Morris County.
Semionotus robustus (Newberry) (1888, p. 36). Triassic, Newark group: Boonton, Morris County.
Semionotus tenuiceps (Agassiz) (1833–36, p. 159). Triassic, Newark group: Boonton, Morris County.

Family LEPISOSTEIDAE

Lepisosteus knieskerni Fowler (1911, pp. 150, 151). Cretaceous (?): Monmouth County, Type: Acad. Nat. Sci. Phila. 2264.

Subclass TELEOSTEI
Order ISOSPONDYLI
Family PACHYRHIZODONTIDAE

Conosaurus bowmani Gibbes (1851, p. 10). Cretaceous: Burlington County.

Family ENCHODONTIDAE

Enchodus ferox Leidy (1855, p. 397). "Blue marl of Monmouth County" (either Navesink (upper Cretaceous) or the Shark River (Eocene), probably the former); "Greensand at Freehold in Monmouth County" (Navesink marl); Burlington County; Haddonfield, Camden County (Woodbury clay); Vincentown, Burlington County (Manasquan marl of the Vincentown limesand).
Echodus gentryi (Cope) (1875, p. 362) (*Phasganodus*). Miocene (?), (Kirkwood formation?): Shiloh, Cumberland County Type: Am. Mus. Nat. History.
Enchodus oxytomus Cope (1875, p. 278). Cretaceous, known only from type.

Order HAPLOMI
Family ESOCIDAE

Ischyrdiza mira Leidy (1856, p. 221). Cretaceous (Woodbury clay): Haddonfield, Camden County.

Order BERYCOIDEI
Family BERYCIDAE

Hoplopteryx insculptus (Cope) (1869, p. 240) (*Beryx*). Cretaceous: Monmouth County (Navesink marl); Hornerstown (Red Bank formation). Type: Am. Mus. Nat. History.

Order PERCOMORPHI
Family SPHYRAENIDAE

Sphyraenodus speciosus (Leidy) (1856, p. 221) (*Sphyraena*). Miocene: Cumberland County; Vincentown, Burlington County.
Sphyraenodus silovianus (Cope) (1875, p. 362). Miocene: Cumberland County. Type: Am. Mus. Nat. History.

Family XIPHIIDAE

Embalorhynchus kinnei Marsh (1869, p. 228). Eocene: Squankum, Monmouth County.
Istiophorus antiquius (Leidy) (1855, p. 397). Cretaceous (?): Burlington County.
Istiophorus parvulus (Marsh) (1869, p. 227). (*Histiophorus*). Eocene: Squankum, Monmouth County. Type: Yale Peabody Mus.
Istiophorus homalorhamphus (Cope) (1869, p. 310). Eocene: Squankum, Monmouth County; Vincentown, Burlington County.

Family SPARIDAE

Commyodus irregularis (Cope) (1869, p. 33). (*Phacodus*). Miocene: Shiloh, Cumberland County.

Family LABRIDAE

Phyllodus elegans Marsh (1869, p. 229). Eocene: Farmingdale, Monmouth County.
Phyllodus curvidens Marsh (1869, p. 229). Miocene: Shiloh, Cumberland County.

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JOURNAL OF PALEONTOLOGY, VOL. 20, NO. 5, PP. 514–516, 1 TEXT FIG., SEPTEMBER 1946

OPTIMUM CONDITIONS FOR THE PHOTOGRAPHY OF FOSSILS

FRANCO RASETTI
Laval University, Quebec, Canada

ABSTRACT—For best definition, photograph thin objects larger and deep objects smaller than natural size, whatever the final magnification desired for the positive.

IT MAY NOT be useless for a physicist to point out some consequences of the principles of optics that must be kept present when photographing fossils or other three-dimensional objects. To be sure, an expert photographer can more or less approach the optimum conditions empirically, but an understanding of the theory leads to the desired result much more quickly than haphazard experimentation.

Poor definition of the photographic image may be essentially due to the following factors:

(1) Aberrations of the lens.

(2) Grain size of the photographic emulsion.

(3) Diffraction, that is, effects due to the finite wavelength of light.

(4) Lack of focusing.

Contrary to widespread belief, lens aberrations usually represent a negligible factor in the photography of fossils, although they may strongly affect landscape photography. The reason is that in photographing fossils other factors require that the aperture of the lens be so small that aberrations become negligible. Moreover, there is no need of using a wide angular field, hence the correction for astigmatism becomes almost useless. In most cases even a simple achromat, if properly used, will yield optimum results when photographing fossils.

It may also be pointed out that the advantages of using high-grade anastigmatic lenses under the conditions generally obtaining when photographing fossils become illusory. These lenses are corrected for aberrations (spherical aberration, astigmatism, etc.) only when used to photograph an object situated at infinity, that is, when the image is formed in or near the focal plane. When used to photograph an object in natural size or moderately enlarged they present little advantages over a simple achromat.

Grain size usually does not affect the results, at least when a fine-grained emulsion (such as the Eastman "Process") is employed. Such a slow, unsensitized, fine-grained emulsion is also strongly recommended for other reasons. Its sensitivity is limited to the shorter wavelengths of the visible spectrum, thus somewhat decreasing the effect of diffraction (see later). It can be developed in bright red or orange light with obvious advantages.

We thus come to the discussion of the two important factors, diffraction and lack of focusing.

Even an ideal lens under perfect focusing does not give a point image of a point source, owing to the finite wavelength of light. The image of a point is rather a circle, whose diameter is directly proportional to the wavelength and inversely proportional to the diameter of the lens. Thus diffraction effects become stronger the narrower the diaphragm employed.

When photographing a three-dimensional object, the camera will be focused on an average plane of the object, while its farthest and nearest parts will be more or less out of focus. To decrease the effects of this lack of focusing, one must reduce the aperture of the lens as far as possible. However, when the aperture is excessively reduced, diffraction will spoil the image more than greater depth of focus will improve it. We must seek a compromise between an effect which requires a wide aperture and one which calls for a narrow aperture. The following is a quantitative discussion of the optimum conditions resulting from these two factors.

An elementary mathematical analysis of the problem leads to the following results.

(1) Let t be the "half-depth" of the ob-

ject, that is the difference in depth between an average plane, supposed to be in focus, and the nearest (or the farthest) parts; and λ the wavelength of light. It can be proved that the smallest detail that can be distinguished on the object (or, better, on the portion that is the least in focus) has the linear dimension:

$$d = 2.2\sqrt{\lambda t} \qquad (1)$$

where all the lengths are expressed in centimeters.

(2) The ideal limit expressed by the above formula can be attained with a lens of any focal length. Thus *all lenses, whatever their focal length, will yield identical results when properly employed.*

(3) *The ideal limit can be attained, for a given lens, whatever the size of the image with respect to the object* (within reasonable limits). Thus it is entirely immaterial whether the desired magnification is obtained directly on the negative, or whether a smaller negative is subsequently enlarged. This is true provided the optimum condition for the diaphragm, to be set forth in the next paragraph, can be fulfilled.

(4) The ideal diameter (or aperture) a of the diaphragm is determined as follows. Let l be the distance between the object and the lens. Then:

$$a = 1.1l\sqrt{\lambda/t} \qquad (2)$$

Fulfillment of condition (2) will lead to the ideal definition of the image expressed by equation (1). The phrase "within reasonable limits" in paragaph (3) means that, for a given distance lens-object, it may be impossible to fulfill condition (2) because it would require a wider or narrower diaphragm than any available on the lens. In the first case, we must move the object closer to the camera, in the second case farther.

Let us consider a numerical case. Assume that we photograph the object in natural size. The two distances object-lens and lens-image will both be equal to twice the focal length of the lens f. Thus $l = 2f$, and $a/l = a/2f$ will be one-half of the numerical aperture a/f, which is usually marked on the diaphragm (for example, the numerical aperture may vary between 1/4.5 and 1/22). Equation (2), writing $\lambda = 4.10^{-5}$ cm (violet light), yields an optimum aperture $a = f/17$ if the half-depth of the object is 0.5 mm.; $a = f/25$ for a half-depth of 1 mm.; $a = f/34$ for a half-depth of 2 mm. It will be noticed that most lenses are so built that condition (2) cannot be fulfilled in the last case, because the iris diaphragm cannot be made narrow enough. The difficulty can be solved either by using a makeshift diaphragm, or more simply by placing the camera farther from the object (this will require a wider aperture) and subsequently enlarging the negative to the desired size. The final result will be identical in both cases.

This remark applies particularly to the photography of deep objects. For example, the optimum conditions for photographing in natural size an object of 2 cm. half-depth would require an aperture of $f/108$.

Figure 1 gives curves (for different object depths) of the linear dimensions of the smallest resolvable detail plotted against lens aperture, for unit magnification. It will be noticed that the height of the minima is proportional to the square root of the thickness, according to equation (1). The minima are rather broad, showing that small deviations from the optimum aperture will produce no appreciable effect on the sharpness of the photograph.

Thin objects will require a wide aperture. Under these conditions, the optimum aperture may become so large that aberrations represent an essential factor in determining the definition of the image. For example, for $t = 0.01$ mm., the theoretical optimum aperture varies between $f/4.5$ for high magnification and $f/2.25$ for unit magnification. Probably no existing photographic lens is so free from aberrations as to give a sharper image at $f/4.5$ than at $f/9$ (as an ideal lens would); hence in this case the best thing to do is to reduce the aperture to $f/9$ or $f/12$, and use high magnification (of the order of 10) in order to be as near as possible to the theoretical optimum aperture.

A device that will somewhat improve the definition of the image in the case just discussed is the following. Most anastigmatic lenses (all the unsymmetrical ones, for example of the Zeiss Tessar type) show strong aberrations when the object is close to the lens and the image far from it, since these lenses were designed for landscape photography where they work under the opposite conditions. If we use such a lens,

as it is ordinarily attached to the camera, for photographing a near object under high magnification, we will get a poor image unless the aperture is strongly reduced. The obvious solution of the difficulty is to reverse the lens, that is, turn toward the object the side that was meant to face the inside of the camera. Then the lens will work under the conditions for which it was designed. In the case of unit magnification either position of the lens will be just as bad, hence the advice is not to use unit magnification unless condition (2) calls for an aperture of the order of $f/18$ or narrower.

From the preceding discussion we see that in general it will be convenient to photograph thin objects larger and deep objects smaller than natural size, whatever the final magnification desired for the positive.

Finally a few words may be said about the relative merit of a photographic lens and of a microscope for photographing small objects. The microscope objective is so designed as to be highly free from aberrations at wide numerical apertures; this is obtained by sacrificing the wide angular field which is an essential feature of most photographic lenses. The wide aperture produces sharp images at high magnifications but leaves little depth of focus. We have seen that the optimum aperture is entirely determined by the depth of the object. Probably a microscope gives better results than a photographic lens when condition (2) calls for a numerical aperture of the order of 1/10 or wider; this happens when the half-depth of the object is less than 0.04 mm. For any object deeper than a few tenths of a millimeter a good photographic lens will generally yield almost as good results as the wave nature of light makes it theoretically possible to obtain with any optical system.

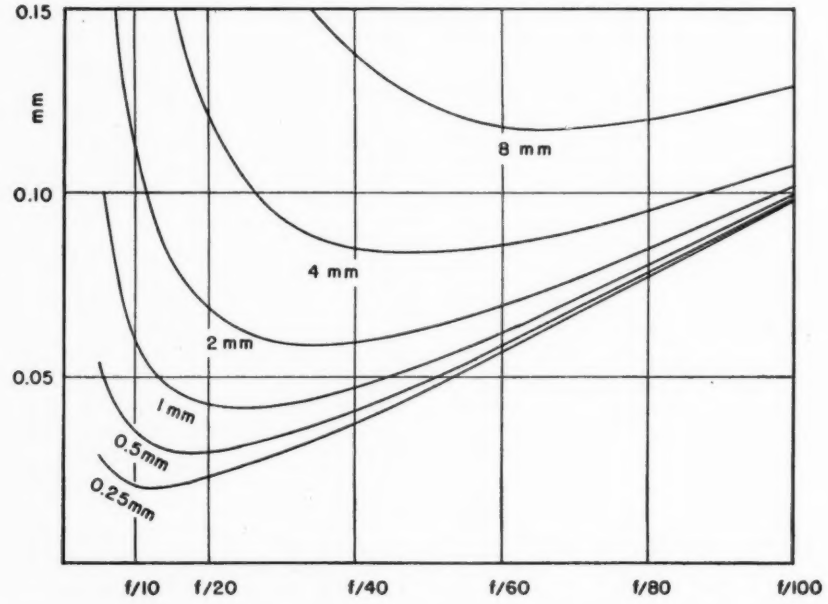

FIG. 1—Theoretical effects of diffraction and depth of focus on image sharpness. The size of the smallest resolvable detail (in millimeters) is plotted against lens aperture for six different values of the object half-depth. The curves are plotted for unit magnification; for a magnification much greater than unity the optimum aperture will be half as wide as indicated by the position of the minima.

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PALEONTOLOGICAL NOTES

DEADERICK COLLECTION OF FORAMINIFERA

LLOYD G. HENBEST
Geological Survey, Washington, D. C.

The life of William Heiskell Deaderick, lately a physician at Hot Springs, Arkansas, recalls a time when many of the outstanding contributions in the arts and sciences were made by physicians. Few micropaleontologists knew or had heard of Dr. Deaderick, despite the fact that he made an important contribution to their science. He was best known for his practice of medicine, his authorship of numerous articles and two books on malaria, syphilology, and tropical diseases, and for leadership in the social applications of medical science. His sole publication in paleontology was "Cretaceous Foraminifera from the Marlbrook marl of Arkansas," of which he was joint author with J. A. Cushman. This article was published in volume 18, number 4, of the Journal of Paleontology in 1944. His principal contribution to paleontology, however, was his fine collection of Upper Cretaceous Foraminifera, which he bequeathed to the United States National Museum.

For several years Dr. Deaderick practiced as a hobby the collection and identification of the Upper Cretaceous Foraminifera of southwestern Arkansas. As a resident of Hot Springs he lived near sources of important faunas and therefore was able to collect more thoroughly, perhaps, than specialists who lived at a greater distance. He prepared and identified his specimens and mounted them in standard microscope slides. The mounting and labeling show exceptional care and neatness.

His collection includes approximately 3,500 slides. Of these, about 300 represent faunal assemblages or taxonomic series. Almost all the rest are slides representing individual species from a locality. A hasty estimate, based on 50 slides taken at random, indicates that at least 75,000 specimens are so classified and mounted. His register of localities contains 403 entries, some of which proved barren according to his notes.

William Heiskell Deaderick was born in Knoxville, Tennessee, February 7, 1876, the son of Thomas Oakley and Josephine (Heiskell) Deaderick. He attended the Southwestern Presbyterian University, 1891–1895; the medical department of the University of Louisville, 1895, 1897; and received the degree of doctor of medicine from Vanderbilt University in 1898. He married Miss Ava Van Leer Lusby on January 8, 1921, who survives him. He died March 11, 1945.

Dr. Deaderick practiced medicine at Clarksville, Tennessee; Marianna, Arkansas; and finally at Hot Springs, Arkansas, until his retirement. He held various responsible positions in the Government Hospital at Hot Springs. He was managing editor of the American Journal of Syphilis; fellow and member of the Board of Governors of the American College of Physicians; fellow of the London Society of Tropical Medicine and Hygiene; member of the American Society of Tropical Medicine; and he was a member or a collaborator with various other American and foreign medical and public health societies. He was joint author of a book on "The edemic diseases of the Southern States," published in 1909; and he contributed several articles on medical subjects to journals.

A further indication of his broad interests in natural history is shown in two articles he wrote, one of which outlined the history of ornithology in Arkansas, and the other listed the birds in the Hot Springs National Park and vicinity.

The size of Dr. Deaderick's collection of Foraminifera and the evident care with which he prepared it form some measure of the time and energy he must have devoted to it. It makes one suspect that his intellectual curiosity gave him little rest, but it

is to such restless souls that the better qualities of our civilization owe their existence.

When I visited his home to prepare his collections for shipment to the United States National Museum, I could see from the character of his collections and other evidences of his work that it would have been a pleasure to have known him. He hungered for association with naturalists. Happily for micropaleontology, his frustration in that respect did not discourage him from substantial contribution to that science, for his collection adds materially to the already extensive resources of the national collections for research and for economic paleontology.

PUBLISHED BY PERMISSION OF THE DIRECTOR, U. S. GEOLOGICAL SURVEY.

SALTERMYA, NEW NAME FOR ANTHRACOMYA SALTER 1861, NOT RONDANI 1856

KATHERINE VAN WINKLE PALMER
Palaeontological Research Institution, Ithaca, N. Y.

The name *Anthracomya* Salter 1861 (Mem. Geol. Survey Great Britain, Iron Ores of Great Britain, pt. III, p. 229), proposed for a well-known pelecypod of the Coal Measures, is preoccupied by the dipteran insect *Anthracomya* Rondani 1856 (Diptera ital. Prodrome, I, p. 87). I, therefore, propose to substitute the name *Saltermya* for it. The genotype of *Saltermya* becomes *Saltermya adamsi* (Salter).

JOURNAL OF PALEONTOLOGY, VOL. 20, NO. 5, P. 519, SEPTEMBER 1946

SOCIETY RECORDS AND ACTIVITIES

ANNUAL MEETING OF THE PALEONTOLOGICAL SOCIETY

The annual meeting of The Paleontological Society for 1946 will be held at the Hotel Stevens, Chicago, December 26 to 28. Because of expected delays in printing, the closing date for the reception of abstracts for inclusion in the program has been advanced to October 15. Nominations for membership must also be in the hands of the Secretary on or before that date. Blank forms for abstracts and nominations may be obtained from the Secretary, H. E. Vokes, Department of Geology, The Johns Hopkins University, Baltimore 18, Md.

NOMENCLATURAL NOTES

RECENT PUBLICATIONS OF THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE

The following publications were issued 25 June 1946:

OPINIONS AND DECLARATIONS RENDERED BY THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE

Vol. 2, Part 46.—*Opinion 176.*—On the type of *Conulinus* von Martens, 1895 (class Gastropoda, order Stylommatophora) (Opinion supplementary to Opinion 86). Price 2s. 1d.

Vol. 2, Part 47.—*Opinion 177.*—On the type of the genus *Euchloe* Hübner (1819) (class Insecta, order Lepidoptera) a genus based upon an erroneously determined species. Price 2s. 1d.

Vol. 2, Part 48.—*Opinion 178.*—On the status of the names *Serphus* Schrank, 1780, and *Proctotrupes* Latreille, 1796 (class Insecta, order Hymenoptera), Price 2s. 1d.

Vol. 2, Part 49.—*Opinion 179.*—On the type of the genus *Princeps* Hübner (1807), and its synonym *Orpheides* Hübner (1819) (class Insecta, order Lepidoptera), genera based upon erroneously determined species. Price 2s. 1d.

Vol. 2, Part 50.—*Opinion 180.*—On the status of the names *Sphex* Linnaeus, 1758, and *Ammophila* Kirby, 1798 (class Insecta, order Hymenoptera). Price 3s. 1d.

BULLETIN OF ZOOLOGICAL NOMENCLATURE

Vol. 1, Part 8. Price 6s. 7d.

REVIEW

GEOLOGY AS A PROFESSION, by Ann R. Taylor. National Roster of Scientific and Specialized Personnel Vocational Booklet No. 1, Department of Labor (Superintendent of Documents, Government Printing Office, Washington, 10 cents), 1946, pp. 1–19, figures 1–4.

This little booklet is designed primarily to give information to vocational advisers but serves also quite well to inform high school and college students about the possibilities of a career in geology. Its chapter headings indicate the substance: The Geologist and his work, Opportunities for women, Geological occupations, Related fields of employment, Beginning jobs and advancement, Conditions of employment, Growth of the profession, Postwar outlook for geologists, Qualifications, Training, and Getting started. Though the pamphlet was written by a layman, it was prepared with the advice of some 16 geologists and it gives a quite accurate and reasonably detailed account, as indicated by the chapter headings. It is nicely illustrated and clearly written, though the professional geologist may find it a little simple in style and lacking the enthusiasm which he naturally feels might be introduced in a booklet designed to describe the most attractive of all the professions! The statements about some branches of geology are perhaps a little oversimplified; yet the style is unaffected and the wording is terse and pointed. The nature of geologic field work, the kinds of training required, the possible outlets in the profession, and the expectable salaries are all set down, and useful suggestions are made about entering the profession, suggestions that would be especially valuable to an isolated youngster not able to meet a geologist for personal conference. As such, the booklet is strongly recommended for those who wish to answer in a direct fashion the oft-repeated query, what outlet is there for geologists and what are the conditions of their employment and of their life? The reviewer knows of nothing comparable in this specific field and urges teachers especially to secure a copy for casual perusal by such young men and young women as may want advice in respect to this field.

CHAS. H. BEHRE, JR.

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